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THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 900 men. Its membership is divided into two principal classes, viz.: MEMBERS and ASSOCIATES. Members are divided into two classes, viz.: RESIDENT and NON-RESIDENT, — the former comprising those residing within the limits of New England, while the latter class includes those residing elsewhere. The INITIATION fee for the former class is FIVE dollars; for the latter, THREE dollars. The annual dues for both classes of Active membership are SIX dollars. Associate membership is open to firms or agents of firms engaged in dealing in water-works supplies. The initiation fee for ASSOCIATE membership is TEN dollars, and the annual dues TWENTY dollars. This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

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PIPE EXTENSION CHARGES.

BY NICHOLAS S. HILL, JR.*

[*Read March 9, 1921.*]

Mr. President and Fellow-Members of the New England Water Works Association,— It is not often that I have the pleasure of coming to your meetings in Boston, but I have prepared a little paper on a subject that I know has bothered a great many of the water-works fraternity in other parts of the country, and I thought probably it had caused some trouble to those working along the same lines in New England.

It might be well to say that I make no differentiation between municipally owned and privately owned water works so far as the economic principles of water supply are concerned. By that I mean to say that, whether a plant is publicly or privately owned, in order for that plant to succeed and to give service it is necessary that the revenues should equal the fixed charges on the plant, — that is, the interest and sinking fund charges in the case of a municipal plant, and the interest and depreciation reserve in the case of a privately owned plant, — the operating expenses and taxes.

Now, that is a basic principle — and every charge which is made for water service is based on the fundamental principle that the revenues must equal the expenses. It may be, of course, in a municipal plant, that all of the money is not taken from one pocket,— that is, from the water rates. Some of the revenues may come from water rates and some from general taxation. Under a properly devised system of charges in a private water company, some of the revenues should come from the water rates and some from taxation. That is, I mean to say, for example, that fire service revenue should come from taxation, because fire service is a property benefit and should not be assessed upon the water-taker as such. But with these minor differentiations the principle holds, and it holds in regard to pipe extensions as well as to any other element of water charges.

This subject is but a small part of the entire question of charges for public service, but it is very vexing at times to operators of water-works plants.

* Consulting Engineer, New York City, N. Y.

With the present conception of a public utility, whether publicly or privately owned, it is not fair for utilities to incur a cost which places an unfair burden upon consumers already connected with the system. The extra cost of an extension which does not pay necessarily places an unfair burden upon existing consumers. The reason for this is obvious. The utility is entitled to earn a fair return on the fair value of the property. Every extension which does not pay a fair return, therefore, must of necessity be recouped from the rates earned by the pre-existing plant. Now, every utility in a growing community is called upon continually to extend its services into new territory. A man may build a house a thousand or fifteen hundred feet from existing lines. He makes an application for the extension of a main to give him water service. The total amount which he may pay for water under the rate schedule is a drop in the bucket compared to the total revenue required to pay a fair return on the extension, for this revenue must not only include a fair return on the investment in the extension proper, depreciation on the extension proper, and the cost of maintaining the extension proper, but also that extension's proportion of the expenses of the entire property which may be fairly and reasonably chargeable to that extension. By the last I mean to say that whenever an extension has been made it becomes a part of the entire system and must bear its proportionate share of the costs of the entire system.

Now, the unfortunate part of the situation is that the accounting system of a great many water plants is not so framed that it is easy for them to allocate the general costs on the entire system to a new extension in a definite and accurate way. The problem of ascertaining the fair return on the extension proper, the taxes on the extension proper, and the depreciation on the extension proper is simple, but the allocation of a fair proportion of the gross cost on the entire system to the extension proper is not so easy.

I think the greatest stumbling block in connection with the problem of charging for extensions is that there is too great a desire for mathematical accuracy. The problem is not one of ascertaining the proper charge to the last mill. The problem is fairly to allocate costs so that the extension will pay a just and reasonable proportion of the general expenses of the plant. Whether the extension charge is 90 per cent. of what it should be or if it is 110 per cent. is immaterial, for it is almost impossible precisely to charge 100 per cent. of its proportion to the extension; but with almost any system of accounts a reasonable allocation may be made which will make the extension bear a fair proportion of the general expense.

If the rate structure of a water works is properly developed and cost is distributed between fixed or static costs and proportional costs, the problem is not so difficult. As a rule, the proportion of the so-called fixed charges on the property — that is, the proportion of the fair return, taxes and depreciation on a plant which may properly be allocated to fixed service or static costs — varies between 30 per cent. and 50 per cent.

in an average water-works plant. Similarly, the proportion of operating expenses on the entire plant chargeable to fixed service or static costs varies between 15 per cent. and 40 per cent. The total fixed service or static costs, which do not vary in proportion to the amount of service taken but remain stationary whether service is taken or not, amount to from 20 per cent. to 40 per cent. of the total cost of service in an average water works.

Boiled down to the simplest form, the charge which must be made for pipe extensions so that a water works may be reasonably reimbursed for their cost includes the following:

a. Fair return, interest, taxes and the cost of maintenance of the extension proper.

b. The extension's proportion of the gross fixed service or static fixed charges on the entire plant. The proportion of the gross fixed charges of the entire plant chargeable to fixed service or static cost, as previously stated, varies from 30 per cent. to 50 per cent. of the fair return, taxes and depreciation on the entire plant.

c. The extension's fair proportion of the fixed service or static operating expenses of the entire plant. The operating expenses chargeable to fixed service or static costs, as previously stated, vary from 15 per cent. to 40 per cent. of the operating cost of the entire plant.

It is obvious, therefore, that the first step in the determination of the fair charge for a pipe extension is to ascertain the cost per lineal foot of such an extension. Some water works prefer to use average prices for every extension of the same size and to base their charge per foot of the extension proper on that average cost. That involves some discrimination, because the price of laying pipe varies in different parts of the territory served. In some parts, rock excavation may be encountered; in other parts, water; in other parts, pipe laying may be cheap. It is more satisfying to the public and strikes people as fairer when the applicant is told: "We will make an estimate of the cost of this extension, and having made such an estimate we will submit it to you. Your charge will be based on the actual cost of the extension. If when the extension is laid the cost is less than estimated the charge will be reduced accordingly. If more, we will charge you no more than the estimate." Under such circumstances the thing to do is to make the estimate cover the cost, and that may easily be done so there is no serious loss. On the other hand, the applicant is gratified if the water works comes back with a notification that there is a reduction in the estimate of the cost of the extension.

Now, having determined the cost of the extension, it is easy to estimate the fair return, taxes, and depreciation on it, as well as the maintenance cost.

The second step is to ascertain the fair proportion of the fixed service or static costs of the entire plant chargeable to the extension. To do this it is necessary first to ascertain the proportion of the total fixed charges

and operating expenses of the entire plant which may be properly allocated to fixed service or static costs.

Having done this, the total fixed service or static cost of the entire plant may be reduced to a convenient unit basis, as, for example, so much per foot of main. A charge of so much per foot of main for the extension's share of the gross fixed service or static cost does not take into consideration the size of the main to be extended and, therefore, it is more equitable to reduce these costs to the inch-foot basis. By inch-feet in an extension is meant its length multiplied by its diameter. Thus a 6-in. extension, 100 ft. long, will have 600 in.-ft.

By dividing the total fixed service or static costs of the entire plant by the number of inch-feet in the distribution system, ascertained by multiplying the length of each size of main in the distribution system in feet by its diameter in inches, the cost per inch-foot of the fixed service or static charge may be determined. Multiplying this cost per inch-foot by the number of inch-feet in the proposed extension fixes its proportion of the total fixed service or static cost. The rule, therefore, for determining the proper charge for an extension may be stated as follows:

1. Ascertain the cost of the extension.
2. Determine the annual cost of the extension, including:
   a. Fair return on the cost of the extension.
   b. Taxes on the extension.
   c. Depreciation on the extension.
   d. Maintenance on the extension.
3. Take from 20 per cent. to 40 per cent. of the gross cost of service (gross cost of service equals fair return, taxes, depreciation, reserve, and operating expenses) as the proper portion chargeable to fixed service or static costs.
4. Divide the total fixed service or static cost by the number of inch-feet in the distribution system to determine the proper fixed service or static charge per inch-foot of main.
5. Multiply the number of inch-feet in the proposed extension by the fixed service or static charge per inch-foot as determined to ascertain the fair proportion of fixed service or static costs which should be allocated to the extension.
6. Add the fixed service or static charge for the extension to the costs chargeable to the extension proper to obtain the total annual costs chargeable to the extension.

Now comes the question as to how the consumer is going to pay the cost of an extension, and in my judgment it is better to have a flexible rule by which the individual preference of the applicant or guarantor for the extension may be satisfied. Some prefer to pay a sum sufficient to cover the cost of the extension at the time the extension is made. Others prefer to pay an annual sum equal to the estimated annual charge for the

extension; or, in other words, to pay for the extension in installments. Some water works allow the applicant to pay for the entire cost of the extension, but such a payment does not cover the cost of an extension, as it saves the water works nothing but the interest on the money which it would have to secure to pay for the extension. If the guarantor is allowed to pay for the cost of the extension it should be understood in the extension agreement that the difference between the revenue actually received from the extension and the fair annual cost of the extension as determined shall be deducted year by year from his payment until such time as the revenue from the extension is sufficient to pay the annual charges against the extension, and that there will be returned to him only the net balance due him after deducting the total annual cost from his deposit.

A better way to handle a flat payment is to estimate what the total annual charges on the extension will be for a covering period, say ten years, and to require the guarantor to deposit this sum with his extension agreement. In such a case the extension agreement will provide that only the actual differences between revenues from the extension and charges to the extension will be deducted, and any balance remaining at the termination of the extension contract will be refunded to the guarantor.

Another way, as I have already suggested, is to have the guarantor guarantee the annual revenue required to pay the annual charges for the extension, and if this is done it is necessary for the guarantor to furnish security so that the water works may be assured that the annual charges for the extension will be paid. This may be done by requiring the guarantor to file a surety bond, or bond endorsed by reputable citizens of the community, as sureties who are satisfactory to the water works.

As soon as an extension goes into service it usually pays some revenue. Statistics which I have collected on different water systems indicate that a large percentage, possibly 80 per cent. or 90 per cent. of all extensions, pay the extension charges within ten years. It is undesirable to have long extension agreements, as it increases the number of such agreements outstanding unnecessarily, making unnecessary bookkeeping and unnecessary trouble. Moreover, there is some question as to whether or not a special extension does not within a certain reasonable time, whether it pays or not, become a part of the distribution system, so it is usually a good plan to agree to return the balance due from a cash deposit, or to release the bond under the annual payment plan, at the end of ten years. The water works will suffer very little loss on this basis, and it removes many causes of complaint against extension charges. The extension contract should provide in any event that it will be automatically cancelled whenever the revenue received from the extension equals or exceeds the amount required to pay the annual charges on it. In the case of a cash deposit, the balance due is returned at the period of cancellation whenever it occurs; and in the case of a guarantee the bond is canceled in the same way. In that way the extension takes its place as a permanent part of

the distribution system as soon as it commences to earn sufficient to carry it and it ceases to be a special extension.

There is one more point that I should touch upon, and that is: What revenues should be deducted from the gross charges above outlined? The methods of charging for service are so different in different water works at this time that it is almost impossible to make a general rule on this question. I can do no more than outline the principle involved.

In the case of many extensions a water works will be immediately possessed of the income from the hydrants set on the line. If the entire fire service revenue of a water works is obtained from hydrant rentals it would be unfair to deduct the entire revenue from hydrants from the extension charge, as a portion of this charge goes to repay the water works for the fair return, interest, depreciation and maintenance of the hydrant and its connections.

Where fire service charges are paid on the inch-foot basis, the inch-foot revenue on the extension is a proper deduction. Where the hydrant charge is a nominal one and only sufficient to cover the fair return, depreciation, taxes, and maintenance of the hydrant, the hydrant charge should not be deducted. The revenue which a water works receives from consumers along a line cannot all be treated as a proper deduction from the extension charges. A sufficient amount should be reserved from the water-service revenue along the extension to pay for a fair return, depreciation, taxes, and maintenance of the meters and service connections, as well as the inspection, repairs, and renewals of meters and the reading and billing of meters. This will usually amount to from 40 per cent. to 60 per cent. of the minimum charge. The rule in relation to water-service revenue from consumers along the line should be, therefore, to deduct 40 per cent. to 60 per cent. of the minimum charge from the water revenue received from each consumer and apply the remainder as a credit to the extension charges.

I have made this outline as brief as possible, but I think I have laid down principles which I am convinced are right after working out extension agreements in a number of places. Extension agreements must be modified in individual cases to suit special conditions, but if they are properly prepared and if pains are taken to explain to the public just what they mean, there is little or no dissatisfaction and the water works receives a material revenue from special extensions. In one company that I know of the revenue from extension contracts amounts to between $25 000 and $30 000 a year, and that indicates the amount of discrimination of which a water company may be guilty in making extensions without a specific charge. Were there no extension contracts in the case mentioned, the other consumers on lines already existing would have to carry that $20 000 or $30 000 a year.

There is one thing more I should like to touch upon. Sometimes it is difficult for a water works to decide whether an extension is a special

extension or an extension which the water works is obliged to make for the purpose of giving adequate service in territory which is already covered. The tendency, of course, is to secure all of the revenue possible from extensions, but it sometimes happens that the distribution grid is not thoroughly connected up and extensions should be made to give proper circulation. An extension made under these conditions does nothing more or less than perfect the grid to give good service, and, when an application comes in for an extension which is necessary to complete proper circulation, no extension charge should be made.

I would urge that in all cases the consumer be given the benefit of the doubt, because I believe in the long run it pays always to give the consumer the benefit of the doubt. Such cases are not frequent. Usually, special extensions are capable of being easily fixed as such, because as a rule such extensions lead away from the existing distribution system for the purpose of supplying an individual consumer who builds on the outskirts of the town. When cases do arise, however, where a consumer builds within the distribution grid on a street where a main has not been laid, it is well to give the consumer the benefit of the doubt.

Discussion.

Mr. Frederic I. Winslow.* I should like to state the policy in Boston for the last thirty or forty years in regard to pipe extensions, which for twenty-five years were in my charge.

The system in Boston has been, during that time, to base the charge simply on the length of pipe multiplied by $1.30, which was for many years the cost of laying 6-inch pipe in ordinary soil. No matter what the size actually laid was, we charged $1.30 a linear foot down to the front of the house as the cost basis. We then took the income from the house, estimated on the schedule rate, as there were few meters, and if that amounted to 6 per cent. of the cost of laying the pipe, the pipe would be laid. This plan worked very well.

Of course, when a street was first opened up, a person building a long way from the main pipe line — because there the land cost less and it cost less to build, and these were the first on the street to ask for water,— if the income was not at least 6 per cent., was called upon to make up the difference multiplied by five. If the pipe cost $500 to lay, on a basis of $1.30 a foot, requiring $30 a year, and this house would yield but $15, he was taxed $75 for a five-year term. This amount was deposited in a bank, as a separate account. If any one built on that line within five years, the first comer got back all that was paid in to the city on that line, up to $75, so that he might get back at the end of the five years a part of his deposit, or perhaps the whole of it — oftentimes he did get back the whole of it.

* Division Engineer, Metropolitan Water Works.

Of course the laying of the main pipe meant more buildings; it increased the demand for the land, because land is more valuable, and can be used to better advantage, as we all know, if there are water pipes in the street.

In regard to hydrants, for a long time Boston had a charge of $18 for a hydrant, paid by the city. That was added oftentimes to offset a low revenue, which made very much less to be paid by the water-taker. Later, it was reduced to $2 per hydrant. I think that now they charge nothing for hydrants — at least, they did not the last I knew.

This system has worked well in Boston, and has worked little hardship, as viewed from the standpoint of a water-works man.

Mr. Francis T. Kemble.* Mr. President, I think that Mr. Hill's paper contains food for a lot of thought. My experience has been that the majority of pipe extensions prove of good service afterwards.

I know of four different methods in regard to payment. Of these I think the method just spoken of, the inch-foot basis, is a particularly fair one. I know that with some companies other than my own, the laying of pipe on a system of a guaranty of certain revenue has proved a source of great annoyance, — a discussion every time a bill was rendered. Where a developer pays the entire cost, I have known cases where it has been difficult to make them understand that they were fairly dealt with, particularly where a single company was developing more than one tract and found the cost of piping some streets amounted to considerably more than others. As a general rule, if the developer is at all successful with his property, manages to advantage, the rebates that he gets because of house connections or hydrants bring him back the money he has had to lay out, without considering that the value of his property has been raised because of having been piped for water.

There is one other method which I do not think has been mentioned that has been adopted by some municipal companies, that I believe has worked to advantage, and that is charging the abutting property so much per front foot on property on streets in which pipe is laid.

Mr. Caleb M. Saville.† In the matter of laying these assessments, it is becoming a considerable question in some of the towns and cities — not perhaps so much the matter of what the assessment shall be, but how that assessment shall be laid.

In Hartford, and I think also in most of the New England States, but not so much in other sections of the country, we have what is known as a "guaranty." That is a guaranty to pay a certain per cent. of the cost of the extension. There are some things about this method that work hardship, and I will try to outline some of them.

The general scheme is that somebody who owns a house on a new street, perhaps over a thousand feet down, wants a pipe extension. Per-

* Secretary New Rochelle, N. Y., Water Company.
† Engineer of Water Board, Hartford, Conn.

haps there are two or three lots which have been opened up on that street, all on one side, let us say. We say to them, "Yes, we will lay that pipe provided you will guarantee 10 per cent. of the cost of laying the extension." Now this agreement is a joint and several guaranty; it is a personal guaranty, and has nothing to do with the land. There is no lien on the land, and if the guarantor moves away or becomes bankrupt there is no way of enforcing collection.

In one city that I know of in Connecticut — Bristol — the cost of pipe extension, through an amendment to their charter, has become a lien on the property. Whether or not that is a wholly good method I prefer to let some one say who has given study to the matter of special assessments.

Now, the men that undertake to put this pipe in, 1 000 ft. long — five of them, we will say — have made themselves personally responsible for the cost of the work. Perhaps they have 60-ft. lots all on one side of the street. That leaves vacant land on one side of the street, and perhaps also between the houses there are vacant lots. Perhaps on the vacant side the land is owned by one person, — a farmer, — and he does not care to develop it. Now he pays nothing because his name is not on the guaranty. The people who guarantee alone are responsible.

The pipe goes in and the people who are responsible for it get their water. Then one of the vacant lot men who would not sign the guaranty applies for a connection, and gets it, with all the benefit and none of the responsibility.

Besides this, there is the increase in value of all abutting land. Immediately a pipe is put into a street it increases the valuation, and the real estate people are very keen in advertising that there is city water in the street.

Now, my question is, — and I wish very much that it might be discussed here to-day very briefly: What is the best way of handling such a proposition, — of handling these extensions? I should be very glad if Mr. Hill would say what he has found in his experience.

Mr. Hill. I think Mr. Saville brings up a most interesting point, and one of the most difficult points in connection with extension charges. I purposely omitted reference to the property assessment method of paying for extensions, because I tried to obviate as far as possible differentiation between a private water company and a municipal plant, and, of course, the property assessment method of securing extension costs is not possible with a private water company. However, I do believe that the method of assessing abutting property for extension charges in municipally owned plants has much in its favor and is worthy of serious consideration.

Touching upon Mr. Saville's point as to the unfairness between the guarantor and others who come in on a new extension, it has seemed to me that the discrimination is more theoretical than actual. In the first place, the guarantor, as soon as others come in on the line, receives the

benefit of any deduction in the revenue guaranteed as the revenue from additional water-takers increases, so that not only is his actual cost reduced but he is responsible for his guaranty for a much shorter space of time.

It must be remembered that it is the one who demands an extension whose needs are primarily satisfied, and that when the extension is made the water purveyor has no knowledge of what the revenue is going to be. In order, therefore, not to place an undue burden upon existing consumers by accepting undue risks, some one must be held responsible for the revenue in order not to discriminate against existing takers. The guarantor receives the benefit that he wants to get at the time, and all revenues subsequently obtained from service on that line go as a credit to him, and are deducted from the extension guaranties of the guarantor, so that when you figure it out, discrimination is really not as great as it seems.

Now, if it seems unfair that some individual or group of individuals wants to take advantage of some other individual or group of individuals, and will not become a party or parties to an extension contract, and places the burden upon other individuals or group of individuals of guaranteeing the revenue from an extension, that condition cannot be laid at the door of the water purveyor. That is human nature. You will always find people of the type who will refrain from signing an extension guaranty from which they will benefit, and this cannot be helped. If the individual or group of individuals who will sign want water, then it will be obviously unfair for the water purveyor to refuse to make an extension because of those who will benefit and will not participate in the guaranty.

Now, when the extension contract is once made between a water purveyor and the guarantor, a legal point is involved. There is no way by which other parties desiring water from a given extension can be made parties to the contract except upon abrogation of the existing extension guaranty contract and the making of a new contract. Now, it is obvious that such a course on the part of the water purveyor would be inadvisable, because the chances are that the parties who would not attach their signatures to the original contract will demur in signing any later contract; so the best the water purveyor can do is to place the responsibility for the guaranty upon those who are willing to accept it in order not to discriminate against existing water-takers and to credit these guarantors with all of the revenue which should properly be credited to the extension which they have guaranteed. Under these circumstances, every house that goes on to a new extension reduces proportionately the guarantors' liability and decreases by so much the period during which the guarantors will be responsible. This is one of the minor points which I can see no way of clearing up in the case of a private water company. If, in the case of a municipal plant, property is assessed for the cost of the extension, then, of course, all property can be assessed without discrimination; and for this reason alone it might be a fairer way than any other for assessing pipe extension charges under municipal operation, to say nothing of the

property benefit which accrues to all property owners by reason of having water adjacent to the property.

Mr. J. M. Diven.* Mr. President, I think I have used one method of getting around Mr. Hill's objection, and that is to give the guarantor control of the main as long as the guaranty lasts. If anybody else wants to come in he must deal with the guarantor and make his bargain with him before he will be allowed to attach to the main. In other words, the guarantor can compel others to assume their fair proportion of the guaranty.

Mr. Saville. That would seem to bring the question more into giving the private man some control of the city property — I am talking from the municipal side of it. I wish we might hear from Mr. Gear as to how he does it in Holyoke, because it seems to me that they have worked out a system up there that is good, and if there are any holes in it I should certainly like to know what they are.

Mr. Hugh McLean.† I have always considered that water should be sold at the cost of delivery from the mains to the residences as far as possible, and that all the other benefits, such as fire protection and increased extensions, should be paid for as laid down, thereby putting the cost at the time of the installation on the individual who acquires the benefit, whether the price be high or low at that particular time.

About five years ago our revenues were not increasing fast enough to meet the cost of the desired extensions. For example, a farm, a tract of land out in the suburbs, was bought by some land speculators, and laid out. Now, in former times on petition we would extend the water pipe up all streets cut and laid out, and make no charge for it. But that was in the days when pipe was costing $15, $20, or $25 a ton. When, however, the cost got up to $100 a ton, and labor cost two or three times what it formerly did, it was a different proposition.

So to increase our revenue primarily, and to get some benefit from those extensions other than the revenue from the sale of water, we thought it out and adopted a charge of a dollar a front foot on all new extensions, and have had very good luck with it so far. Occasionally we are confronted with a statement that it is not legal, but so far we have gotten away with it.

If a pipe is laid 300 ft. on a street, and if the man at the end of the street wants the water first, we do not charge the others the dollar a front foot until they take the water. We are wondering whether or not we should amend our rule and make the charge on the other owners at once. Sometimes they say, "We are satisfied with our well water; we don't want the city water now, and don't know whether we will ever want it." But if we can be protected by a lien on that property, so that if it is sold at any time the buyer will know that there is a lien on it, then we will be all right.

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*Secretary American Water Works Association.

† Water Commissioner, Holyoke, Mass.

Awhile ago one of our leading educators bought a place, and found one of these liens was on it, where they hadn't paid the dollar a front foot. We would not put the water in until he paid. He threatened to contest our rights and took legal advice; but we have gotten away with it so far.

It seems to me the simplest way to do is to finish your job while you are at it.

If the pipe line is laid, the real estate man sells his lots, and gets the benefit, and the builder is getting a good price for his work, all the other utilities are being paid for, and I think the people benefited should pay a proper amount for the extension of pipe lines. We have so far maintained the same low price for our water, but have got to provide additional revenue, and that was one of the steps taken. A dollar a front foot does not cover all the costs, but we thought that it was reasonable in view of the fact that some of the present users had their extensions put in for nothing when the prices were low.

Mr. Patrick Gear.* In making this front foot charge, we found that there were two streets side by side, and pipe was laid in one that was opened up nine or ten years ago on which a couple of houses were built. The lots were sold for $50 more on the street where the charge was made than they did on the older street, so that we put a service charge on all vacant lots on the older street. We do not care how long the pipe has been in,— it may have been in forty years,— we now apply a service charge and are getting some revenue from that. We also have $10 for a 1-in. tap, besides charge for installing the service, $15 for $1\frac{1}{4}$ in., $20 for $1\frac{1}{2}$ in., $25 for a 2-in., $35 for a 4-in., and $50 for a 6- or 8-in.

In Holyoke we furnish water so cheaply that if the streets were all built up to-day, our charges would not cover half the cost. The places where we get the revenue is where they build up in the air. If all of our streets were built up with one-family houses, we could not pay our expenses in Holyoke.

There are some of those fellows who try to beat us a little now and then, in a very jolly way. Take the case of a man who is on the corner of a street, and there has been a pipe on one of those streets for twenty years. The other is a new street which has just been opened up. He says, "I will tap on the pipe on the old street and I won't have to pay anything." We say, "No; you must connect on the side street; the other is a main pipe and you can't tap it; but we will charge you by the front foot." Now, he has a 50-ft. frontage on the main street and 150 ft. deep on the side street, but in that case we only charge him the $50.

Mr. David A. Heffernan.† Mr. President, the plan used in Milton works out very well. In cases where the extension of mains in unaccepted streets is applied for, the cost of the work is estimated and a deposit of 25 per cent. of the cost required. This insures an income of 5 per cent.

* Superintendent Water Works, Holyoke, Mass.
† Superintendent Water Works, Milton, Mass.

annually on the outlay for a period of 5 years. This deposit is placed in a savings bank. If the applicant desires he may pay this 5 per cent. each year and leave the bank deposit intact. If not, the department withdraws from the bank a similar amount. At the end of 5 years the applicant receives the balance of the deposit with the interest it may have earned.

MR. REEVES J. NEWSOM.* I would like to ask Mr. Heffernan, in the working out of his plan, if the original development is made by some man who is building houses to sell, and if he makes a deposit to cover an extension for three lots, say, and then shortly afterwards sells two or more of the houses, what becomes of his deposit in the bank?

MR. HEFFERNAN. We hold the man who makes the application, and do business with only one man. He has to make the deposit, and that is held up until the end of the five years.

MR. GEORGE F. MERRILL.† Mr. President, I believe that Mr. Gear has the fairest way of distributing the cost. I do not know what authorization they have for it, but, at any rate, it seems to me there is a chance right there for a little legislation that would make it a whole lot more equitable to the people that own lots on streets that are built up. I think the way Mr. Gear has worked it out might be taken as a basis for legislation.

MR. A. R. HATHAWAY.‡ This matter has been quite a problem in Springfield for some time, as some of you may know. Our system is somewhat similar to the others; we have a guaranty which, when signed, becomes a personal agreement, as Mr. Hill says, and is not a lien on property.

We sometimes receive notices from people who signed such an agreement, that they have sold their property abutting on the extension and that we should look to the new owners for any charges under their guarantees.

We immediately tell them that *they* are the persons who are responsible, as they are the guarantors, and that they should arrange with the new owners for taking care of such charges, if they so desire, when we send the bills to the original signers. We have had very little trouble in that direction.

I was glad to hear Mr. Hill bring out one point in his paper, and that was his recommendation of a time-limit for such agreements. Most of our difficulty in collecting charges under our guaranties has been due to the one undesirable feature of a possible " forever " period of responsibility.

Our guaranty reads that the signers shall pay upon demand the annual amounts set against their respective signatures until such time as the revenue derived from that particular extension,— from themselves as water-takers, or from other water-takers on that line,— shall equal or exceed the aggregate amount of the guaranty. Naturally most of our guaranties

* Water Commissioner, Lynn, Mass.
† Superintendent Water Works, Greenfield, Mass.
‡ Water Registrar, Springfield, Mass.

are soon canceled by the water revenue received, while some run for many years, and a few bid fair to "go on forever." At various times I have suggested to our water commissioners the adoption of a time-limit,—preferably a ten-year period,— which is the limit recommended by Mr. Hill in his paper, as I understand it.

I have in mind one place (I cannot recall the name now) where they have a five-year limit. The adoption of a limited period, I think, would do away with the trouble we are now having at times.

Only last week a young woman called at our office to ask how long her guaranty was likely to run, and she was told it might be "forever, unless some additional water-takers become connected to that main, or the present takers let the water run through their meters, so that our revenue for that line during any particular year will equal the guaranteed amount."

It seems that she owns a lot on a street where a small extension was wanted by two other parties who had put up houses, and who signed a guaranty for certain amounts, and who persuaded her to sign for five dollars a year, also.

She stated that she does not expect to build on her lot, but may some time sell it. For six years, I think, she has been charged the $5.00, and it was when receiving the last bill that she made her inquiry.

While the "forever" period was naturally not pleasing to her, she said she supposed her lot was really worth more for having a water pipe run by it, and that she supposed the charge must be all right. I told her that the only way I could see to help her out was to sell the lot to somebody who would build on it, or else build on it herself, and she finally appeared to accept the situation.

But, as I stated before, I am of the opinion that a proper time-limit of five or ten years would be the means of helping us out in the matter and would in my judgment be the proper thing.

I do not know how you can make the guaranty any stronger than a personal agreement in Massachusetts, so long as the state laws do not make such charges a lien on property.

There is one thought that occurs to me, and that is that in making such extensions it should not always be considered necessary to assess the entire cost, or the full interest equivalent on the cost, on the parties to be at once benefited. I have read a number of opinions handed down by Public Utility Commissions in different states (pertaining to privately owned utilities, such as water, electric, gas, etc.), where they questioned the right of such utilities to *refuse* proper extensions of service in cases where the entire interest charges, or costs, were not previously guaranteed or met by the petitioners. In other words, such utilities were held to a certain degree of obligation to serve the people who may build beyond the present limits of their mains or lines, notwithstanding the fact that a full return might not be at once realized from the extension investment. So that, if this be true in a measure concerning private utilities, how much

more should it apply to a municipally owned utility! This point, it seems to me, should be borne in mind when we are thinking of and discussing this subject.

Mr. Saville. Mr. Hathaway speaks about the five-year period. I think there is a law on the statute books of the state of Minnesota saying that it shall be paid within five years.

I should like to say that one of the jokers in this scheme Mr. Hathaway has spoken of — that is, this guaranty forever, which we have in force, too, and have run up against it in one place — is that it says that until the revenues are equal to the water rates. That means that if any man is keen enough, and has it in mind, he will let his water run for one year until he gets up to that guaranty, and then having got to the place where the requirements of the guaranty are fulfilled, he can shut the water off and he is through with the guaranty.

Mr. George A. King.* Mr. President, there is one point which Mr. Hathaway spoke about, viz., the transfer of the guaranty to the new owner. We have a city solicitor who ruled that the water commissioners had a right to charge a special assessment because of special privileges, and that if we made this extension we could require a new owner of the property to pay that, provided he took the water. That is, we could refuse to let him have the water except he paid the guaranty which his predecessor had made. Our guaranties are for five years.

Mr. William A. MacKenzie.† Mr. President, Wallingford has the same arrangement as in Springfield, and it has worked out successfully. It seems to me in a municipal plant that the vacant lots are enhanced in value, and the taxes derived from that particular development are greatly increased, and indirectly the municipality receives the benefit which perhaps was partially brought about by the department in laying water mains through the new section. I think the ten-year clause would be a very just proposition to bring into this consideration of the percentage of the cost, and then have the limit ten years, and the money derived from taxes would indirectly help to carry the cost of the extension. The private plant might be somewhat different.

Mr. Hill. I want to make one or two remarks in closing this discussion.

I have no particular preference for any method of assessing extension costs. My intention this afternoon was to bring to the attention of the Association, first, the absolute necessity and fairness of making an extension charge; and, second, that a fair extension charge is a computable thing however it is assessed.

I think objection to the extension charge is largely because such charges have been made in a hit-or-miss fashion, without regard to the method by which the charge should be determined. Now, it is perfectly

* Superintendent Water Works, Taunton, Mass.

† Superintendent Water Works and City Engineer, Wallingford, Conn.

possible, whether an extension charge is to be levied on the inch-foot basis at so much per foot of pipe, as a fixed sum, or assessed at so much per front foot of abutting property, or in any other way, to ascertain what the fair charge should be for an extension under each condition, and with this fact borne in mind it will be possible to adopt the basis of charging which is best suited to the local requirements, to the municipal or private plant, and to meet the conditions and laws in the various cities governing the collection of such charges, for these laws also differ.

That is the one point that I wanted to bring out in closing this discussion, — that proper extension charges may be computed, and in making such charges the basis for the charge should be accurately ascertained.

Mr. McLean. In Holyoke the engineer estimated the cost of laying the pipe on this new farm tract at about $2 a foot, so that rather than charge them the full expense we went halves with them, figuring that it would be giving them about what the former water-takers used to get for nothing.

RELATIONS BETWEEN PLUMBERS AND WATER-WORKS SUPERINTENDENTS.

BY G. WILBUR THOMPSON.*

[*February 9, 1921.*]

Mr. President and Gentlemen, — Your business is largely outside of my zone of activity, and the few things that I may suggest are those that have appeared to me through my many years engaged in the plumbing business, but what I am to dwell upon largely will be the activities of the plumbing industry at the present time as compared with those of two generations ago, and down through to the present time, and in so doing I may be able to point out, in a way, a relative contrast in your work through this time as well. We are very closely allied, as no plumbing would be of any use except for the supply of water; and, on the other hand, very little water would be needed, in comparison, if the use of plumbing had never been generally adopted.

The plumber has to deal with the two greatest elements of creation, — fire and water, — and I will ask your indulgence to diverge for a moment and enter into a personality, that I may surround myself with the proper scenery or background by approaching the main subject in a reminiscent way.

I was born up in the woods of New Hampshire, and when very young, long before I even knew the definition of the word "plumber," and before I had learned to respect the great value of fire and water if properly controlled, I knew the absolute terror and destruction of both, as I had witnessed them when left to their own fury and uncontrolled. I can even recall at this moment the terrible nightmare of the burning of a large set of farm buildings, including all of the live stock, and two elderly people as well; and I suffered many times during my childhood the fear and dread of the fury of water during the heavy fall rains and spring freshets, when the little brook that flowed a few yards in the rear of my home would rise many, many fold above its normal capacity, and sweep onward and take everything before it.

There were several dams on this particular stream, where were located sawmills, gristmills, tanneries, etc., as were so common in the old days, and I can recall at this time in a heavy fall of rain when the upper and largest dam gave way, and on came the rushing water in all its fury and power, sweeping before it all of the other dams and bridges. What particularly impressed and affected me most was that it swept all of the soil from the

* President of the Massachusetts Association of Master Plumbers.

land connected with my little home, taking an orchard of about fifty grafted fruit trees, flooded the house, and came near taking it along as well, — practically ruining our home, which meant so much to us at that time. These, gentlemen, were my first impressions of fire and water, and they have dwelt with me down to the present time.

I left home when about eighteen years old and bound myself out for three and a half years to learn the business, as was the custom then, and served my full time. I then went into the employ of the Boston, Concord & Montreal Railroad, which was afterwards absorbed by the Boston & Maine, as a journeyman, and remained in their employ for thirteen years, and during the last five years had charge of the heating, plumbing and waterworks of the White Mountain Division, extending from Nashua and Portsmouth, N. H., to Fabyans, and lateral lines, and during that time I had a very broad experience in water supply, ranging from and including the old-style suction pump, windmills, gravity, steam pumps and hydraulic rams. The most difficult thing of all was guarding against the cold we had in the mountains. Twenty-five years ago I severed my connection with the railroad and engaged in the plumbing and heating business at Newton Centre, where I am still located.

Two generations, or fifty years ago, there was very little plumbing in the large cities and none in the country, as many of you gentlemen know, and even down to thirty years ago there had not been very great progress made in the plumbing industry, for at that time the fixtures were all cased in, and the water-closets largely were either of the Zane, the Detroit, or Pan styles, which, *especially* the first two mentioned, were of the vilest character, and not much improvement over the old dry vault. From that time on, the industry began to take on a new life, when enamel ware first began to appear and the open plumbing began to be introduced. From that time down to the present you all realize the great transformation that has taken place, and especially so during the last decade.

When I was elected last April to the presidency of the State Association, I, like all others, wished to do something different from my predecessors, and the first thing that appeared on the horizon was to change the style of the old stereotyped stationery that had been used for so long, and I conceived the idea that I might, if possible, procure a cut of a complete bathroom as installed in 1893, the year that our association was organized in Massachusetts, and place it at the top of the letter sheet with the year "1893," and at the opposite corner put a picture of an up-to-date bathroom of the present time. This I did. I had much difficulty in procuring the old cut, but finally I was able to get it and to do this with much satisfaction. My object in doing it was to remind every member of the craft, both young and old, who might see these pictures in contrast, of the very great improvement that has been made in our industry during the last generation, — and it has been especially marked during the last decade.

When I first engaged in the business for myself it was quite rare to have more than one complete bathroom in the ordinary house, and all of the plumbing in the house was put in at an expense of a few hundred dollars, whereas to-day the real estate brokers tell us that people generally will hardly care to look at a house unless it has two or more complete bathrooms, and all other plumbing accessories as well.

In 1916, I completed the installation of plumbing in a residence that cost in round numbers twenty thousand dollars. To-day it would be nearly double that amount. I simply speak of this to show to what extent the industry has grown and to what extent it is demanded at the present time.

Without modern plumbing the high commercial buildings would be impossible, the gymnasiums and hospitals much less efficient, and at the same time it has proven itself not only to be a great comfort, value and satisfaction in every-day life, but it has become a necessity to such an extent that the towns, cities, states and even our National Government are enacting laws to compel all of the great industries to install proper plumbing in their factories and places of business where help is employed, and this plumbing is required to meet every demand to safeguard the health of the operative while at work, as well as at his or her own home.

Another great advance that has come about within a comparatively short time is the public comfort stations. All of you gentlemen will agree with me when I say that no other name could be better applied to these stations than "comfort," for they are that to the fullest meaning of the word, and when we think of them as comfort stations we don't want to lose sight of the fact that there is a moral value in it, in the way of protecting the privacy of the sexes to a large extent, as if in their own homes; and again, it tends to protect the comfort and health of the person by being able to respond to the call of nature instead of postponing it, which, as we all know, is a very dangerous thing to do.

Another, and what I deem as a very encouraging outlook of the business from a physical standpoint, is that it is no longer a city proposition and necessity, but it is being introduced and enjoyed in the country homes as well. This phase of the business is going to have a very far-reaching and beneficial influence upon the young people in inducing them to remain on the farm and to adopt and carry on agricultural pursuits as their life's vocation, as has been done by their parents and perhaps grandparents for many generations before them. And why? Because when the young go away to the city, or to school, they enjoy all of the up-to-date life that is afforded them at these places, and after once enjoying this life, it is very hard for them to return to the farm and be deprived of it, and the longer they remain away the harder it is for them to return; and that is the principal reason why so many in the past have abandoned the farm and gone to the city to dwell.

But this condition is being changed, and will continue to be changed, as time goes on, by reason of the fact that the time has arrived when people

living in the country may enjoy practically all of the privileges of city life. To-day the farmer is in close touch with the outside world by means of rural delivery, the telephone; and, yes, I might add, the auto, and now through the addition of electric lights or gas and modern plumbing, as you will see in many country homes, — but perhaps more so in the West or Middle West.

What inducements has the city over the country to offer the young man or woman from the farm? To-day the farmer's son and daughter, by means provided through the many splendid state agricultural colleges, and the up-to-date farming implements, become so educated and efficient that they may return to the farm and produce more and better products on ten acres of land, and with very much less energy, than their parents did before them on fifty acres. It is a well-known fact that the strength, health, and prosperity of a country depends to a large extent upon the success of its agriculture, and every inducement and encouragement should be given in that direction by the government and the people as a whole, and the above means when fully carried out will no doubt bring about the very best results for both the people and the country at large.

The plumber in the past has been treated as a huge joke. He has been cartooned, maligned, and more abused by means of cheap, stale, and uncalled-for jokes circulated through the newspapers and magazines, than all other artisans and professions combined. In the old days it might have been warranted to some extent, as the old-time plumber was a mechanic and not a business man, but to-day the whole condition is changed. I personally resent any of the cheap epithets and inferences applied to the industry as of the past, and our state and national organizations have convinced some of the leading papers and magazines of this country that it was not for their best interests to continue, and some of them have already apologized within a year for some of their publications that our state associations took exceptions to.

I am a plumber, not by choice but by condition; but as long as conditions made me a plumber I have tried to be a good one, and now that I am a plumber, I will say that I am proud of it. And why? First, because I am a producer, — for I am deeply impressed with the fact that any individual or any industry that produces that which will contribute the greatest good to the greatest number of people is the greatest benefactor; and, without being egotistical, I cannot see where any other industry adds more to the comfort and satisfaction of life to-day than the plumbing and heating industry. It is the very vitals of the home, the school, the church, and the factory, and modern life could not continue and improve morally and physically without it.

And then again I am proud to be engaged in the business because it requires long experience and good judgment to equip the enormous buildings of this time with heating and plumbing; and, again, because it is interesting, as no two buildings or propositions are alike; and, again, be-

cause we are the only artisans who are required to pass a rigid examination by a board appointed by the state before we are allowed to go forth as journeymen. Why? Because it is, in a way, a profession as well as a trade, for the public depends to a large extent upon our industry for the protection of its health. We protect, as far as possible, not only the physical but spiritual as well, for it has been said that cleanliness is akin to godliness, and where we fail it only remains for the doctors, ministers, and undertakers to do the rest.

And now, last but not least, I am proud I am a plumber from the fact that no other business has made such an advance as our industry has during the last decade, and the possibilities are still greater for the future than in the past by reason of the great educational campaign that is being carried on through the efforts of our state and national associations, the National Trade Extension Bureau, and our splendid trade journals.

The Trade Bureau is made up and maintained by the manufacturers of plumbing and heating supplies and the Master Plumbers of the United States. Well-qualified field men are furnished by this organization and distributed all over the country, each to cover a certain section, who are at the disposal of the local associations for the purpose of teaching them how to arrive at costs or overhead in business; how to show goods; and, in fact, everything that may improve our business from every angle. This is without doubt the greatest educational campaign ever inaugurated by any business, and through its efforts we feel very hopeful that our industry will not be longer treated as a necessary evil, as in the past, but looked upon as one of the greatest and most respected of all industries, and through these efforts we are encouraged to entertain the hope that we may soon be recognized as justly entitled to occupy one, if not the highest altitude in the construction of business, a position which is due us and which we rightfully should have attained long ago.

Now, gentlemen, in setting forth the business as I have, I have not lost sight of the fact that you are entitled to your share of the glory; for, in a way, plumbing is wholly dependent upon the supply of water, and the possibilities of furnishing water for the increased demands has been just as much of a problem, and perhaps even greater, to meet all of the changed conditions, and the able hydraulic and mechanical engineers who have been able to furnish all of the machinery and lay-out, and perfect the great water supplies, are worthy of the greatest praise and appreciation.

One of the greatest problems that we have to meet is the pipe question, and that can only be met by the analysis of the water in each locality, and the chemical action of the water on the different kinds of pipe. That is a local problem. We have been greatly disappointed, in Newton and Brookline, in the use of brass pipe. Owing to the large amount of carbonic gas contained in the water, its action upon the pipes either crystallizes them to such an extent that they become as brittle as clay and break off at the thread, or they become thoroughly pitted the whole length of the

pipe. I have done work all over New England, and it has been very interesting to see the different results, in the various localities. On the whole, for every locality and every condition, I believe the lead pipe has given far the best satisfaction.

In the beginning, I mentioned that I had only one or two suggestions to make, which are: That the smallest supply to any building should not be less than one inch inside diameter, increasing in size according to the demands of the household. The distance from the main to the building should be considered, and especially so under a low pressure, where a larger pipe should be used, as it is a fact that friction has much to do in reducing the pressure and volume of water delivered as the length of pipe increases. In other words, much more water will be delivered when the delivery end is only 25 ft. away than when it is 1 000 ft. away.

I believe, gentlemen, that this suggestion is worthy of your consideration, at least to some extent; but the greatest mistake of all, as my experience has proven to me, is the meter. Almost invariably, where there is an inch or larger main, a meter will be placed that has only a half-inch inlet and outlet. Twice within a few months I have been called into two dwellings where there were several bathrooms, and on account of this very trouble when they drew water in one place it could not be had elsewhere in the house to any extent. On examination I found the piping in the house of ample capacity, but the trouble was wholly due to a half-inch meter.

Therefore I would recommend, for the good of the householder, that the meter should be equal to delivering as much water, — or, in other words, the inlet and outlet of the meter should be equal in size to main supply inside of building. From my point of view the meter, as it has been used, is the chief thing that should receive your attention in an endeavor for greater efficiency and satisfaction to all concerned.

There are other things I might mention, but I fully realize that this is a very dry subject, long-drawn-out and uninteresting, therefore I will close by reading this piece of doggerel rhyme that has recently come into my possession, and which seems quite appropriate for a symposium of this kind:

"The drouth is on from shore to shore;
The drouth is on forever more;
The flames are seething from many throats,
For the loss of liquids is getting their goats.

"The drouth is on to this extent,
It's driving some people to the devil hell bent, —
With raisins and malt and inventions all new,
They are making concoctions well known as 'home brew.'

"Now ye men of distinction who keep on sale
The best of all liquids, renowned Adam's Ale,
Maintain a high test and you'll never relent,
For selling the goods test 100 per cent."

Discussion.

Mr. David I. Heffernan.* I wonder if Mr. Thompson would inform us if he has used the Smith's temperature relief valve which is on the market. This is a pressure and temperature valve. There are several other good relief valves on the market, but this valve is a new one, and from what I understand, it is worth considering.

Mr. Thompson. I will say that I have had experience with about all kinds of relief valves. The whole thing has simmered down to one thing, — that the relief valve is of very little consequence on pressure work, and it has been proven beyond dispute that what makes the trouble is not the pressure, but it is the temperature of the water. You take a temperature of water of, say, 250 degrees, at a pressure of 80 to 85 lb., and if an explosion takes place you will find, according to capable engineers who are in a position to know, that when the boiler gives way the steam expands in the ratio of 1 700 to 1. That is 1 700 cu. in. to 1 cu. in. There is where the trouble lies.

In many tests that have been made, and explosions that have taken place right here in the city, and one in particular that we had pictures of, our association went so far as to get out books and pamphlets and send them to every member of our association in the state, describing it. It has been demonstrated that the very moment that anything gives way under hydraulics, that very instant, as you all know, the pressure is released, it doesn't spend itself to any very great extent; but if you have something that is compressed, like superheated steam, and then it gives way, that is when the damage comes.

You are alluding to Mr. Smith's valve. I do not believe that the pressure valves, as they are called, amount to a snap of the finger. With a valve so constructed that when the temperature of the water gets to a certain point it will melt and fuse the contents of that valve, relief is given before the damage is done.

There was a very bad explosion two years ago, in the South End, which did a tremendous amount of damage, but fortunately there were no people injured. It was proven that there was a relief valve that was supposed to open at 85 lb., — just a few pounds above the natural pressure, — and when the valve was taken off it was found that it would respond to an ounce to what it was formerly set at, and yet this pressure had gone very high by reason of the water being heated into steam. That is where, in every case, so far as I know, the damage occurs.

The only thing that I can say about Mr. Smith is that he has the nearest to it of anything I have seen, in my judgment. There are some things that he has got to correct before it will be used to any very great extent, and those things I think he has in mind at the present time.

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* Superintendent Water Works, Milton, Mass.

Mr. Heffernan. I should like to ask Mr. Thompson if he would recommend putting a check-valve on a service, on the pressure side of a meter, if no provision was made for any relief or vacuum valve on the house side.

Mr. Thompson. I think that would be a very hazardous thing to do. The only relief is when the water can flow back through the meter, and some of the meters, I understand, are so constructed that they won't even allow that.

Mr. Morrison Merrill.* I should like to ask Mr. Thompson what he would recommend to save some boilers on high land from collapsing when we shut the water off suddenly.

Mr. Thompson. The only relief, of course, is a good, reliable vacuum valve.

Mr. Merrill. We can't depend on them.

Mr. Thompson. Of course there is nothing perfect in this world, but nine times out of ten I think a good vacuum valve will respond. That has been my experience. You are referring, of course, to a pressure job?

Mr. Merrill. Yes. A case of this kind occurred in my town last week. A main burst and I shut off the water without any notification, and a boiler collapsed. It was a heavy, copper-riveted boiler, and collapsed almost as flat as it could be if it was rolled out, but when the water was turned on the boiler took its natural shape.

Mr. F. H. Gunther.† That is something which should be embodied in the new plumbing regulations, — that there must be a relief valve on all pressure jobs, and is something which all water-works men have got to contend with. They will shut off a main and perhaps can't shut off all the services. Of course we shall have a collapsed boiler. Even pressure boilers will collapse under certain conditions.

Mr. Thompson. You get a Brown boiler — I am not advertising them — but I do not think you will have any trouble with collapsing under any condition.

Since the pressure boilers and the auxiliary gas heaters have come into common use the whole trouble has occurred. People will forget and leave their gas burners going under the gas heaters. After a few hours, of course, the water is heated to a tremendous temperature.

I was somewhat impressed by the result of these explosions, and I felt as though it was a very bad thing for the plumbers as a whole, because in several law suits the plumber has lost every verdict. In some cases he has been taxed with the expense of fighting the suit as well as the amount of the verdict, and it has cost him $7 000 or $8 000, which would ruin almost any plumber.

Now, I saw and considered that some time ago. I had an idea that when I installed a boiler, if I did everything in the world I could to put it

* Superintendent Water Works, Wakefield, Mass.
† Superintendent Water Works, Dracut, Mass.

in properly, the man for whom I put it in must assume the loss if any explosion took place. So I made a draft of a release, and submitted it to my attorney, and also to another very able one, and to one of the judges of the Superior Court, and each one of them said that this release would hold water. It read like this:

NOTICE AND RELEASE.

In consideration of the warning given to me by ....., who is about to install a gas water heater or coil to a house heater in the premises at ....., and connect the same with a street pressure boiler, said warning being to the effect that grave danger attends the use and misuse of said heater or coil, I hereby agree that said ..... shall be relieved of any and all liability for any accident or damage which may result *to any person or property* from the use of said gas water heater or coil.

.....(Seal)

Owner or Agent

Date.....192..

Recommended and Approved by the Massachusetts State Association of Master Plumbers, Inc.

I had copies of this release printed, and sent them to every one of our master plumbers throughout the state, ten copies to each man, with a circular letter describing what it was for and all about it. A great many of them said no man would sign a release of that character. Their prediction has been disproved in almost every instance. I have put in quite a number of gas heaters and attached them to pressure boilers since that time, and not one person has refused to sign, and several have thanked me for calling their attention to the fact that they have a hazardous thing in their homes. They were not aware of it. That is the very point, — that they are apprised of it and they assume all responsibility if any damage occurs.

Now, that releases the plumber, but it does not release the householder from the possibility of these explosions. I will tell you here, gentlemen, that you want to be mighty careful to watch your gas heaters if you have them on a pressure job, for if you don't you may have to put a new roof on your house most any time.

MR. GUNTHER. That would protect the plumbers, but where does the water-works man come in? I had an experience once, and got out of it simply because I laid it on to the plumber. There was a pressure boiler, modern boiler.

MR. THOMPSON. I can only say that you water-works people wil have to work out your own salvation.

Mr. Gunther. You have some plumbing bills before the legislature at the present time, and if you could embody something in them which would protect the water-works men it would be a good thing.

The President. The only thing that has been suggested, as far as I know, that will protect the water-works men, is the check valve.

Mr. Frank E. Merrill.* There is no water meter made that will stand hot water. If hot water backs up from the house pipes into the meter it will damage it so that it will not register. I should like to ask the gentleman how he expects the water-works people to measure water if there is not a preventive for its coming back into the system.

Mr. Thompson. That is only occasionally. I do not think that you would ever receive enough to affect your meter to any extent.

Mr. A. R. Hathaway.† I just want to refer to the title of this paper, — "Relations between Plumbers and Water-Works Superintendents." I was just turning over in my mind the relation of plumbers to the water-works superintendents, and then the admission Mr. Thompson made that he doesn't know much about water meters. I was wondering if Mr. Thompson as well as the other plumbers would not make more of a study of the meters and perhaps learn a little more about them.

In connection with that, we had an experience in Springfield some time ago. In our new building code we have a plumbing inspector. He has taken some samples and used them in the evening school with some of his plumbers, got them together and given them instructive talks, explaining the workings of the water meter, and I think that we have seen good results in the relation of the plumber to the water-works superintendent.

Mr. Thompson. That is a splendid suggestion.

* Water Commissioner, Somerville, Mass.
† Water Registrar, Springfield, Mass.

THE NEED OF UNIFORMITY IN PLUMBING REGULATIONS.

BY PROFESSOR GEORGE C. WHIPPLE, HARVARD ENGINEERING SCHOOL, CAMBRIDGE, MASS.

It is a popular idea, and I believe a true one, that plumbing costs more than it ought to. Yet the master plumbers say, and I believe they say truthfully, that as a class they are not getting rich. Apparently the excess profits, in so far as they may exist, are going chiefly into the hands of the great corporations which manufacture the plumbing materials. Trades unionism also tends to keep up labor costs in this branch of the building industry, as in all others. There are doubtless abuses in the plumbing business, as in other lines of business, which need correction, but they need not be considered here. We, as sanitary engineers, are more interested in finding out whether there are faults which it is in our own power to correct, whether our designs are more elaborate than they ought to be, whether the materials specified for the work are reasonable and proper. I believe that the subject of house plumbing has not received the attention it deserves from water-works men. The house piping is an integral part of a water-works system; the greatest waste of water occurs in the plumbing fixtures; the soil pipes are an integral part of the sewer system. Cities really have one great hydraulic system, with three separate parts which correspond to the arteries, capillaries, and veins of the circulatory system of the body.

Plumbing is a business regulated under the police power of the state. The regulations for the most part were made many years ago, at a time when it was believed that filth was the cause of certain diseases and that sewer gas was a poisonous substance. This idea of regulation was a perfectly justifiable use of the police power of the state in the interest of the health, morals, and safety of the people. I believe that it is still a perfectly justifiable use of the police power. But since the Massachusetts regulations were made, forty years ago, science has learned much in regard to the cause of disease. It has proved that the danger of diseases being spread by sewer air is very small indeed. On the other hand, it has learned that sewage is a very dangerous substance, that dangers to health lurk around the plumbing fixtures, where there is chance that minute particles of fecal matter may pass from one person to another by the method known as contact. Furthermore, foul odors influence health even though they may not cause acute and recognizable diseases. If, however, the dangers are less than was formerly supposed, it is reasonable that the factor of safety in plumbing designs should be correspondingly reduced in the in-

terest of economy. The importance of having ample facilities for using water is becoming more and more appreciated every year. Standards of cleanliness are rising. We need simpler plumbing, but we also need more plumbing.

In the early days regulations were left largely to local boards of health, and naturally a great variety of rules and methods of procedures were adopted. The better and more prosperous communities were inclined to improve on the regulations of their neighbors. Each little addition usually represented somebody's personal idea, and was not based on scientific knowledge. As a result, we find that at the present time the plumbing rules and regulations of the state are in a chaotic condition. Two cities have regulations based on special acts of legislature. Fifteen cities and towns have adopted the so-called State Examiners' Rules, and in these places the regulations are, therefore, uniform. Seventy-seven cities and towns have regulations made by local ordinances, and there are scarcely two of these which are exactly alike. In addition a few towns have what may be called informal regulations. About 260 towns, however, many of which are of considerable size and population, have no rules and regulations. These differing methods of control have resulted in a great variety of regulations. In many cases they appear to be unduly restrictive. Even within a short distance of Boston there are certain plumbing devices which are required in one place, prohibited in another, and left optional in a third. These differences appear to be quite unnecessary and accomplish no good purposes, serving merely to make trouble alike for architect, master plumber, and house owner, and tending, also, to increase the cost of plumbing, as both the architect and the plumber must take time to ascertain what regulations exist in any particular place.

The increased complexity of the regulation of the details of plumbing has resulted partly from the use of changed materials and new methods of installation of plumbing and house drainage, but it has been due also to changes in buildings themselves, their greater height, the increased number of multiple houses, and the increased number of plumbing fixtures in buildings. These regulations appear in most cases to be justifiable for certain classes of buildings, but when applied to other classes of buildings may be unnecessarily severe.

Of course there have been many changes in business and social conditions since the plumbing laws were established in Massachusetts, and even since they were last revised, in 1909. There has been a gradual change in the methods of doing plumbing work. Manufactured supplies distributed by large corporations have taken the place of much of the work done on the ground. Plumbing work in the house to-day is largely a matter of assembling manufactured products; but while this may require less skill on the part of a craftsman it will always require good judgment. Less work than formerly is done in the plumber's shop. A number of years ago, when cities were smaller, plumbers were engaged on the basis

of financial responsibility and personal reputation and acquaintance; but now that cities have become of large size this personal relation is being lost, and the public must apparently depend more and more upon the system of registration and licensing of plumbers and inspection of the work.

The public often complain of abuses in the plumbing business, of waste of time, of puzzling ideas as to who should do certain kinds of work, of quarrels between plumbers and steam fitters, of difficulties in the purchase of supplies except through master plumbers, and the like. It should be clearly borne in mind that plumbing regulations have little or nothing to do with these things. Business regulations and trades union rules should not be confused with official plumbing regulations.

The enforcement of the plumbing rules and regulations usually involves three steps: first, the issue of permits; second, the inspection of the work; and third, penalties for violations. In the case of cities and towns which have public water supplies or public sewers this system of permit and inspection appears to be necessary, but in the case of small towns it would appear to be less necessary, and the adoption of this system should be left for each community to decide. There is considerable variation in the practice of issuing permits, in the fees required for permits, and in the requirement of a statement, sketch or plan of work to be done. Uniformity in this matter of permit and inspection would facilitate the installation of plumbing and would be a benefit to the people, but it is a matter which to a considerable extent may be left to the local authorities. Where permits are required, they should be issued only to master plumbers.

On the whole, the inspection of plumbing at the present time appears to be carried on in a reasonably satisfactory manner, but there appear to be many cases of non-compliance with the law. The methods of securing compliance with the law at the present time are legal and necessitate court proceedings. The difficulty of this system appears to be that the penalty for violation of the regulation is one that cannot be physically put into effect. The suggestion has been made that the plumbing regulations should prohibit the use of water in a building, except for test purposes, until the plumbing has received approval. At the present time, the gas companies refuse to turn on the gas until inspection has shown that the gas piping is in proper condition, and this method operates satisfactorily.

Many of the present-day difficulties with plumbing cannot be solved by legislation unless concerted action can be obtained among the states. Plumbing supplies are now manufactured by large corporations doing business throughout the country, and it is impossible to regulate many of the details by a law passed in any one city or state. If regulations are too minute they have the result of increasing the cost of plumbing.

The troubles with plumbing are usually much less in new buildings than in old buildings. It is usually the old, worn-out plumbing which results in filthy and unhygienic conditions. Greater attention therefore

should be given to the re-inspection of plumbing already in use. Cheap materials and poor workmanship, however, hasten bad conditions, and it is largely for this reason that sound basic rules and regulations are necessary. Reinspection, which would naturally be a function of the local health department, should be confined to rented houses, which may some day be regarded as quasi-public buildings.

A study of the detailed plumbing regulations, especially those which relate to the subjects of trapping and venting, indicates that many of the regulations should be simplified for small dwellings used by a single family. In multiple dwellings of two or more stories, stoppages or leaks in one apartment may affect the occupants of another apartment, and greater factors of safety are necessary in such buildings than in buildings occupied by a single family. Simplification of the plumbing systems in small buildings will tend to reduce the cost of housing and eventually permit an increase in the number of fixtures installed without additional total expense. Increased opportunities for the use of water in the home will tend to improve the health conditions of the community. This result can apparently be brought about by classifying buildings according to height, occupancy, and use, and by making different regulations appropriate to different classes of buildings.

If the regulations are thus modified so as to provide simple rules for the small, low building occupied by a single family, with more complicated rules for the larger and higher buildings, it would appear justifiable to make these regulations uniform for all cities and towns of the Commonwealth. The best solution appears to be that of providing, first, simple *minimum requirements*, covering merely the most elementary matters of sanitation, state-wide in their application, and, second, other rules and regulations which may be known as the *standard regulations*, and which may be accepted in whole or in part by the local authorities, becoming effective after having been approved by the State Department of Public Health. Provision should be made for modifying these rules and regulations from time to time in order that advantage may be taken of progress in the art and that new devices which prove to be satisfactory may be used. In all cases the enforcement of the minimum requirements and the standard regulations should be in charge of the local authorities.

At the present time the water-piping systems which convey water to plumbing fixtures are not subject to supervision and inspection. This has resulted in unsatisfactory conditions. Plumbers usually install the water piping, the fixtures, and the drainage system as a single job. Competing plumbers therefore are inclined to cheapen the water piping, so that pipes of inferior quality and of insufficient size are installed. As a result the water pipes often become clogged and fail to supply water to the fixtures in the required volume or at the required pressure. The increased use of flush valves, which require water delivered at a high rate for a short time, is an illustration of the need of having the water piping as well as the

drainage system subject to inspection. The supply of water to the fixtures and its subsequent removal should obviously be regarded as a single problem. The possibility of pollution of water by improper connections in the piping system has been demonstrated in many cases. There is another serious problem found in domestic hot water supplies, — corrosion and over-heating not infrequently resulting in explosions, with danger to life and property. Of course, the pipes used for heating buildings by steam or hot water are not intended to be covered by the plumbing regulations.

Some of the most unhygienic conditions resulting from improper house drainage are found not in the cities but in rural districts, as, for example, in summer resorts. Greater attention should be given to such buildings in the interest of the public health. These troubles are not as closely related to the fixtures or the interior piping as to the manner of disposal of sewage and waste water. Local boards of health now have authority to control such conditions, but too commonly they are neglected. Better results would be secured if some of these matters were included under plumbing regulations.

On general principles I am opposed to the concentration of power in the federal and state governments. I have always stood for the advisory powers of the State Department of Public Health, as opposed to the assumption of absolute state control. I believe in the delegation of police power to local authorities, especially in matters which do not seriously affect the public health. Nevertheless, in order to secure that uniformity in the plumbing regulations which seems so desirable in the interest of economy, convenience, and, indirectly, in the interest of health, I see no other way than to have standards set up by the state. After more than a year's discussion of the subject by a special board, the membership of which included Edward C. Kelly, representing the State Association of Master Plumbers; Thomas M. Wilson, representing the New England Association of Plumbing Inspectors; Patrick J. Osborne, representing the Massachusetts Association of Journeyman Plumbers; James C. Coffey, representing the State Examiners of Plumbing, and the writer, representing the State Department of Public Health, a bill has been introduced into the legislature which, if passed, will make it possible for the State Department of Public Health, acting through a special board of supervisors, to clear up the present unsatisfactory situation with reference to the plumbing regulations. The bill does not involve sweeping changes in present methods. It provides for a board of five plumbing supervisors, three of whom shall act as plumbing examiners who will perform the duties of the present plumbing examiners. It provides for certain simple minimum requirements of the most elementary character, uniform throughout the state, but graded for different classes of buildings. It also provides for the setting up of a standard code of regulations which may be accepted in whole or in part by the local authorities. It provides that variations from

the standard shall not be permitted without the approval of the State Department of Public Health, but it also leaves it to each city or town to accept or reject these standard regulations in whole or in part, and in all cases it leaves it to each city and town to enforce the minimum requirements and the standard regulations, if adopted. This appears to be a fair and reasonable adjustment between state control and local control.

It is believed that the adoption of the proposed act and the formulation of minimum requirements and standard regulations as proposed therein will result in greater uniformity in the regulation of plumbing in the state; will make it possible to simplify the plumbing in small buildings and thus reduce their cost; will tend to increase the facilities provided for using water in buildings and thus improve the public health, and will be a substantial benefit to the people of the Commonwealth.

When we consider the almost total stagnation which now exists in the building industry, and the great shortage of houses of habitation, particularly in the cities, we are of the opinion that the opportunity to lessen the tremendous cost of building construction and to encourage a revival of industry is sufficiently apparent to warrant sympathetic consideration of this Association.

WATER DISTRIBUTION IN CONNECTION WITH PLUMBING AND ACTION OF WATER ON METAL.

BY DAVID A. HEFFERNAN.*

[*February 9, 1921.*]

Up to the present, water-works officials have concerned themselves with water supplies to residences and business buildings only as far as the point where the meter was set. This was the general practice, and there the responsibility ended. However, as I pointed out in my paper at Holyoke, we must realize that if we are to strive for the elimination of waste water and reduction of the costs of supply, we must make closer observation and have a more intimate knowledge of what becomes of the water after it leaves the meter.

We have also to pay more attention to water supplies in so far as their action on the medium of supply is concerned. We know that different kinds of waters act differently on different kinds of pipe. I quote from the Report of the Special Plumbing Board:

"1. Soft waters, especially if they contain carbonic acid, are more corrosive to metals than hard waters.

"2. Colored surface waters are usually more corrosive than colorless waters of the same degree of hardness.

"3. Ground waters are more corrosive than surface waters, partly because they generally contain larger amounts of carbonic acid, and partly because they do not form a slimy layer on the walls of the pipe.

"4. Filtered waters are more corrosive than the same waters unfiltered, because they do not form slimy layers in the pipes.

"5. Waters filtered by the process of mechanical filtration are more corrosive than waters filtered by slow sand filtration, because the use of alum increases the amount of carbonic acid in the water.

"6. Waters which are impregnated with sea water, or which have high chlorides and high nitrates due to pollution, are more corrosive than waters which do not contain these salts, because of their dissociation.

"7. Hot water is more corrosive than cold water.

"8. In any particular case one must balance the above-mentioned factors."

From this it is apparent that no set rule can be made to cover all cases, in so far as to recommend one kind of pipe to the exclusion of all others.

Milton gets its supply from the Metropolitan System, and of late we have been troubled with several service stoppages. In one case, that

* Superintendent Water Works, Milton, Mass.

of a service installed only eight years ago, the sidewalk stop was a $1\frac{1}{4}$-in. automatic drip valve with an iron body. In preparing to shut off the water it was found that the valve stem was broken. When it was dismantled we discovered that the stem must have snapped when the water was let on some years before, and the disks had not risen to their full height. The action of the water between the iron body of the valve and its brass disks had been strong enough to almost entirely close the passage through the valve body. In another case, we were changing a stopped meter in a house where strict orders were given by the owner's wife to our man "to be very careful not to allow any moisture to dampen the cellar floor." As he was removing the meter the cement-lined wrought-iron pipe gave way on the pressure side of the lever-handle cock, and not being prepared for the necessity of shutting off the water in the street, you may believe me not guilty of exaggeration when I say that the lady of the house was somewhat upset by the time the water had been shut off. Here, the wrought-iron service with the customary cement lining had been made into a brass ell. In some manner the action between the two metals had eaten them both until only a slight pressure was needed to separate them. Examination showed the ell to be nearly closed up at the end of the pipe in the ell, but a point at the curve of the ell was clear of rust and corrosion.

In the matter of lead pipe we had an experience that surprised me. A business building is supplied with a $\frac{5}{8}$-in. lead pipe, through which a very considerable amount of water passes for its size. We were notified of a stoppage. We had never had a stoppage in lead pipe before, and thought, at first, that the trouble must be where the brass corporation entered the cast-iron main, but this was not so. The only way the pipe could be cleared was by forcing through it, several times, a wad of tissue paper by means of a pressure pump. Nothing hard came out, just black, slimy grease.

We are now lining all our cocks with lead, which, we hope, will eliminate most of the trouble.

From these experiences it may be seen that the action of water on metals is one to which much earnest thought and study must be given if we are to forestall serious trouble later. In this connection, I am convinced that the failure of automatic devices, such as relief and vacuum valves, is due mostly to the action of the water. There are two ways of overcoming this evil. First, the use of pipe and fittings which will not be adversely acted upon by the water; second, the supplying of water which will not attack the pipe and fittings.

There is action between wrought-iron or steel pipe, whether or not galvanized, and brass fittings; between brass pipe and brass fittings. This latter is due to the fact that brass pipe contains 40 per cent. zinc and 60 per cent. copper, while brass fittings contain a lesser amount of copper and really show less signs of corrosion than the pipe.

This matter should be given our most serious consideration and discussion. In the meanwhile I feel that the hot and cold water supplies after they leave the meter should be placed in the new plumbing code, for the protection of house purchasers against unprincipled building speculators, for the advantage of master plumbers who now encounter different plumbing codes in nearly every city and town, and for water departments and companies which should benefit in the decrease of waste water from cheap defective fixtures now sometimes installed.

I can't understand how pipe under pressure of 100 lb. could get into that condition. I was there when the force pump was put on it and the tissue paper came through, and was surprised at the collection discharged and can't understand how that matter could adhere to the lead pipe under that pressure. The action of the pump, with 150 lb. pressure, forced the thing through.

DISCUSSION OF R. S. WESTON'S PAPER: "LEAD POISONING BY WATER."

[December, 1920, JOURNAL N.E. W. W. ASSN.]

BY GEO. C. BUNKER.*

In connection with Mr. Weston's instructive paper on "Lead Poisoning by Water, and Its Prevention," in the JOURNAL of this Association for December, 1920, some data obtained by the author during his studies of the water supply of Gatun, Canal Zone, may be of interest. The raw-water supply of this community is obtained from an impounded reservoir in which the run-off from a watershed area of 1 019 acres is collected. The geological formation underlying the watershed is known as the "Gatun." Mr. Donald F. MacDonald, the geologist, has written:

"The Gatun foundation consists of three members, as follows: (*a*) About 500 ft. of marls and argillites, or clay rocks, and some beds of soft sandstone and conglomerate; this member is bluish-gray but locally contains many brown specks, indicating fragments of organic material; it is rich in the fossil shells of ancient marine life; (*b*) mostly fine, soft sandstone, about 100 ft. thick, containing a few fossils; (*c*) light to creamy gray indurated clay beds. The upper part of the formation weathers into red clay, and except where this is cut by streams it covers the solid rock to a depth of 10 to 25 ft."

As a result of this formation, the alkalinity of the water in this reservoir is low, 15.5 to 24.5 p.p.m., as $CaCO_3$.

The raw water is treated with aluminum sulphate, aërated, passed through sedimentation basins, and treated with lime; filtered through rapid sand filters and disinfected with liquid chlorine. There has been considerable variation in the chemical characteristics of the raw-water supply during the last five years, which renders the treatment of this water more difficult and expensive. For example, the solids have varied from 53 to 86 parts, the alkalinity from 13 to 21 parts, the soap hardness from 6.3 to 26 parts, the iron content from 0.30 to 3.00 parts, the color from 10 to 152 parts, the turbidity from 6 to 46 parts, and the oxygen consumed from 1.55 to 9.8 p.p.m.

The application of lime to the partially decolorized and settled water was started in the first quarter of 1916 because the continued low alkalinity of the raw-water supply of this plant, 14 to 20 p.p.m., with the amount of alum necessary for the removal of the color, produced conditions such that

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it was considered advisable and necessary to increase the alkalinity and decrease the amount of free carbonic acid in the filtered water by the addition of soda ash or lime. Due to the large amounts of chemicals required for the treatment of the raw water during 1916, it was not found feasible to neutralize all of the free carbonic acid in the settled water and maintain a small amount of carbonate (CO_3) alkalinity in it, as it flowed upon the filters, until the last month of the year.

In order to determine the action of the filtered water on lead, 25 ft. of a new 1-in. lead pipe, from the stock on hand, was connected to the 12-in. cast-iron pump discharge main, and laid on the ground. An ordinary brass faucet was placed on the discharge end. Water was turned into this pipe on February 1, 1918, and run continually through it with few exceptions, at the rate of about one gallon per minute from 8.00 A.M. to 5.00 P.M. each day. From 5.00 P.M. to 8.00 A.M. the water remained in the pipe without any circulation, except in a few cases where there was a slow dripping. At approximately ten-day intervals until August 10, 1919, samples were collected of the water standing overnight, and, one hour later, of the running water.

The average changes of temperature to which the water in this pipe was submitted were as follows:

TABLE 1.

Temperatures of Water in Lead Pipe Experiment.

Date.	Time.	First Water Drawn Off. Temperature, Degrees Cent.	Time.	Running Water. Temperature, Degrees Cent.
March 22, 1917.....	8.30 A.M.	26.7	12.30 P.M.	28.5
March 23, 1917.....	7.30 A.M.	24.1	2.30 P.M.	27.2
March 29, 1917.....	8.00 A.M.	23.5	3.00 P.M.	27.6
March 30, 1917.....	8.00 A.M.	24.5	3.00 P.M.	27.5
April 5, 1917.....	9.00 A.M.	27.5	2.00 P.M.	28.5

Determinations of phenolphthalein alkalinity, erythrosine alkalinity, and lead were made on the samples; 2000 c.c. of the samples were evaporated to dryness and the lead determined by the method given in the 30th (1898) Annual Report of the State Board of Health of Massachusetts, pages 577–585. A tabulation of the analyses of 121 samples of water collected during the above period follows.

TABLE 2.

LEAD PIPE EXPERIMENT.

(Results expressed in parts per million.)

Date.		Carbonate (CO_3) Alkalinity.	Erythrosine Alkalinity as ($CaCO_3$).	Lead.	
				Water Standing Overnight.	Running Water.
1918.					
February	1	1.1	16.0	...	0.13
	2	1.1	16.0	0.15	0.25
	3	1.1	17.0	0.20	0.15
	4	1.1	16.0	0.27	0.37
	5	0.6	16.0	0.65	0.06
	6	0.8	17.0	0.37	0.20
	7	1.1	16.0	0.50	0.10
	8	1.5	16.0	0.35	0.15
	9	1.9	16.0	0.55	0.10
	10	1.1	16.0	0.50	0.12
	20	1.5	16.0	0.45	0.25
March	2	1.1	16.0	0.32	0.12
	12	1.1	16.0	0.32	0.10
	22	1.7	15.0	0.25	0.05
April	1	1.1	15.0	0.15	0.25
	11	0.6	15.0	0.30	0.15
	21	0.6	15.0	0.65	0.25
May	1	0.6	15.0	0.22	0.12
	11	Trace.	16.0	0.12	0.12
	21	Trace.	15.0	0.35	0.15
	31	2.4	15.0	0.30	0.15
June	10	1.2	18.0	0.55	0.60
	20	0.6	17.0	1.20	1.10
July	1	1.2	18.0	0.15	0.10
	10	0.6	19.0	0.07	0.07
	20	0.6	16.0	0.15	0.07
	31	0.6	16.0	0.25	0.10
August	9	Trace.	16.0	0.30	0.10
	19	Trace.	17.0	0.15	0.12
	29	Trace.	18.0	0.15	0.12
September	8	0.6	18.0	0.25	0.10
	18	Trace.	18.0	0.10	0.07

TABLE 2. — *Continued.*

LEAD PIPE EXPERIMENT.

(Results expressed in parts per million.)

Date.	Carbonate (CO_3) Alkalinity.	Erythrosine Alkalinity as ($CaCO_3$).	Lead.	
			Water Standing Overnight.	Running Water.
1918.				
October 8	0.6	15.0	0.10	0.10
18	0.6	16.0	0.15	0.12
28	0.6	16.0	0.22	0.20
November 7	1.2	19.0	0.20	0.18
18	Trace.	18.5	0.20	0.30
28	0.3	19.0	0.25	0.20
December 17	No report.	...	0.35	0.23
27	0.9	19.0	0.15	0.20
1919.				
January 6	1.2	21.0	0.20	0.15
17	Trace.	19.5	0.12	0.10
27	1.2	19.5	0.10	0.11
February 6	1.2	18.5	0.15	0.10
17	1.2	18.5	0.18	0.10
28	1.2	19.0	0.12	0.10
March 20	2.4	23.0	0.15	0.10
31	2.4	21.5	0.12	0.10
April 10	1.8	23.0	0.20	0.15
21	4.2	22.0	0.30	0.12
30	1.2	21.0	0.30	0.22
May 10	2.4	22.0	0.22	0.20
20	1.2	22.0	0.25	0.22
30	1.2	20.5	0.20	0.15
June 10	1.2	20.0	0.18	0.15
20	1.2	18.5	0.25	0.18
30	1.2	20.0	0.20	0.10
July 10	1.2	21.0	0.18	0.12
20	1.9	19.5	0.12	0.15
30	1.9	20.5	0.18	0.12
August 10	0.6	18.5	0.15	0.10

During the first ten days the amount of lead was determined each day. In the standing overnight samples it increased from 0.15 p.p.m. in the first sample to 0.65 p.p.m. in the fourth sample and then decreased slightly to 0.50 p.p.m. on the tenth day. In the running samples, the lead increased from 0.13 p.p.m. on the first day to 0.37 p.p.m. on the fourth day and then decreased to 0.12 p.p.m. on the tenth day.

After the tenth day the lead in the overnight samples fluctuated up and down during the period ending June 20, reaching the high figures of 0.65 and 1.20 p.p.m. on the respective dates of April 21 and June 20 and the low figure of 0.12 p.p.m. on May 11. From June 20, 1918, to August 10, 1919, the maximum lead content was 0.35 p.p.m. on December 30, 1918, and the minimum, 0.07 p.p.m. on July 10, 1918. As an average figure during this period, 0.20 p.p.m. may be taken.

After the tenth day the lead in the running samples fluctuated between 0.12 and 0.25 p.p.m. until June 10 and 20, 1918, when it reached 0.60 and 1.10 p.p.m., respectively. From the latter date until August 10, 1919, the lead varied from 0.07 to 0.23, but 0.14 p.p.m. may be taken as an average figure.

After the collection of the last samples, a section of the pipe was split open and the interior surface found to be covered with a very thin, light coating, — too thin in my opinion to prevent continued action of the water on the lead. In Fig. 1, sections are shown of this pipe and of a galvanized-iron pipe operated under similar conditions and over the same period of time. On account of the heavy deposit in the latter pipe, one would expect the formation of a thicker coating in the lead pipe than was found and is shown in the illustration.

As Mr. Weston has pointed out in the case of the Milford water, the aëration of the Agua Clara supply, with the accompanying increase in dissolved oxygen, undoubtedly increases the corrosive action of the water on lead pipes. Table 3 illustrates his statement at the top of page 253, about the oxygen being used up in water standing in a lead pipe.

TABLE 3.

SPECIAL DETERMINATIONS OF DISSOLVED OXYGEN IN SAMPLES OF WATER FROM A LEAD PIPE.

Date.	Sample.	Time.	Temperature, Degrees Cent.	Dissolved Oxygen.	
				Parts per Million.	Per Cent. Saturation.
March 22, 1917	Standing overnight.	8.00 A.M.	26.7	6.04	73.0
March 22, 1917	Running.	8.02 A.M.	26.8	7.79	96.0
March 30, 1917	Standing overnight.	8.00 A.M.	28.5	6.12	72.5
April 5, 1917	Standing overnight.	8.00 A.M.	25.3	6.35	76.1

Although the free carbonic acid was removed from the water running through the lead pipe by the lime treatment, carbonate (CO_3) alkalinity being present on fifty-two out of the sixty-one days on which samples were

Fig. 1. Coatings on Lead and Galvanized Iron Experimental Pipes.

collected, the action of the water on the lead was not stopped. Under these conditions the action of the filtered water with the chemical characteristics given in Table 4 must be due to its low hardness and alkalinity and to its rather high oxygen content, the combined influences of these factors overcoming the restraining effect of the hydroxyl ions.

TABLE 4.

SUMMARY OF CHEMICAL CHARACTERISTICS OF FILTERED WATER USED IN LEAD PIPE EXPERIMENT.

	Soap Hardness ($CaCO_3$).	Alkalinities.		Color.	Dissolved Oxygen.		Total Solids.	Nitrates.	Chlorides (Cl).
		Erythrosine ($CaCO_3$).	Carbonate (CO_3).		Parts per Million.	Per Cent. Saturation.			
Median	20.8	16.3	0.6	2	7.1	90.7	75	Trace.	6.5
Maximum	30.8	19.1	1.5	8	8.1	103.2	91	0.030	7.0
Minimum	16.9	14.5	Trace.	0	6.0	77.4	63	0.000	5.5

Note: The soap hardness was determined weekly on a seven-day composite sample, the alkalinities were determined daily, and the dissolved oxygen on a catch sample collected each week.

In order to maintain the carbonate (CO_3) alkalinity, as summarized in Table 4 and as given in more detail in Table 2, lime was used as indicated in Table 5.

TABLE 5.

AMOUNT OF LIME APPLIED TO SETTLED WATER.

Month.	Pounds per Million Gallons.	Month.	Pounds per Million Gallons.
1918.		December	47
February	39	1919.	
March	39	January	47
April	50	February	61
May	40	March	51
June	39	April	67
July	30	May	48
August	51	June	47
September	50	July	56
October	56	August	51
November	48		

It must be remembered that the lime is used principally at this plant to raise the alkalinity of the water, and that it would be used even if there were no lead services in the district supplied by water from this plant, so the cost of this treatment should not be charged entirely to the prevention of plumbo-solvency.

Fig. 2 shows the slaking box for the unslaked lime which is shipped from the States either in steel drums or ordinary wooden barrels lined with tin. The milk of lime is lifted by an ejector into one of the duplicate steel tanks. From these tanks the diluted limewater flows into the concrete orifice tank, which carries a float valve to regulate the head over a steel plate in which there is a row of holes of varying sizes. The limewater is

divided into two equal portions, each of which flows through a galvanized iron pipe to one of the settling basins and runs into the settled water as it passes from the first to the second section of each basin. A water wheel is provided for turning the agitators in the tanks.

Pieces of sheet lead, measuring 1 in. long, $\frac{1}{2}$ in. wide, and $\frac{3}{32}$ in. thick, were exposed to the action of the different waters, Nos. 1–7, inclusive, listed in Table 6. The settled water, with an alkalinity of 4.0 p.p.m., a soap hardness of 25.3 p.p.m., a free carbonic acid content of 6.8, and a

FIG. 2. SLAKING BOX, SOLUTION TANKS AND ORIFICE TANK FOR APPLYING LIME TO SETTLED WATER.

Ph value of 4.5±, dissolved 5.0 and 9.5 p.p.m. of lead, respectively, at the end of one and seven days. This represents the character of the filtered water which was discharged at times from the Agua Clara Plant before the use of lime was started. Samples of this class of water collected after standing overnight in a lead pipe of the same length and diameter as used in the experiment previously described, but prior to the start of the lime treatment, were found to contain from 0.3 to 2.33 p.p.m. of lead.

In order to obtain an idea as to the amount of carbonate (CO_3) alkalinity necessary to add to the filtered water in order to reduce the action of the latter on lead, Experiments 2 to 6, inclusive, were made. From these it is seen that the presence of 2.4 p.p.m. of carbonate alkalinity reduces the amount of lead dissolved from 5.0 and 9.5 p.p.m., respectively, at the end of one and seven days, to 1.0 and 1.7 p.p.m. The addition of

4.8 p.p.m. of carbonate alkalinity increases the action of the water on the lead during the first twenty-four hours, but retards it slightly during the seven-day period.

In the case of this water supply, the conclusion may be drawn from these experiments that a carbonate (CO_3) alkalinity of 2.4 p.p.m., produced by the addition of lime, must be maintained in order to keep the lead content of the filtered water, as drawn into houses through lead services during ordinary day use, below 0.1 p.p.m. However, from other experiments which I have made with lead pipe, I do not think this amount of alkalinity will always prevent the lead from rising above 0.1 p.p.m. in the water which stands in the services overnight. In the case of new lead services, even with this amount of alkalinity present, the lead may run as high as 0.50 p.p.m. during the first three months after their installation, and the consumers cannot be depended upon to always waste the first water drawn from the pipes in the mornings. Under the local conditions of operation of this plant, it is difficult to always insure the presence of a carbonate (CO_3) alkalinity of 2.4 p.p.m., so I am of the opinion that in order to avoid any ill effects, due to the consumption of lead, it is best to discontinue the installation of lead services in the district supplied by water from this purification plant.

As far as I can learn, no recognized cases of lead poisoning have occurred in this district, although as Mr. Gage has pointed out there may have been cases of ailments which were intimately connected with the use of water containing more than 0.1 p.p.m. of lead.

In Experiment 9, in Table 6, a sample of disinfected filtered water was collected, immediately after the addition of the liquid chlorine, so that when a portion of it was poured over the piece of lead the residual chlorine amounted to 0.24 p.p.m. By means of a blank, it was found that the chlorine disappeared in one hour and thirty-five minutes from the water. Neither this sample of water nor that used in Experiment 10, which contained a trace of residual chlorine, dissolved any more lead than the filtered water in Experiment 8, showing that the chlorine, in the amount present, did not increase the plumbo-solvency of the water.

Among the other experiments listed in Table 6 are some made with waters of high alkalinities and conductivities, the latter approximating the mineral contents.

In the list of "Some Additional References" in Mr. Weston's paper, the third one refers to a paper by H. Heap, "Study of the Action of Various Waters on Lead," which was published in the Journal of the Society of Chemical Industries, Vol. 32, No. 15, August, 1913. To those who may have occasion to make a study of the subject I recommend this paper as an excellent contribution, both for its review of work done by others and for the experimental work carried on by the author. A list of 28 references to other papers is included.

TABLE 6.—Actions of Various Waters on Lead.
(Houston's Method.)

Source of Sample.	Parts per Million.						Hydrogen-ion Concentration.	Conductivity.	Remarks.
	Reaction to Laemoid.	Alkalinity to Erythrosine.	Soap Hardness.	CO_2.	Lead Found in Water.				
					One Day.	Seven Days.			
Agua Clara Purification Plant:									
(1.) Settled water, not treated with lime	Acid.	4.0	25.3	6.8	5.0	9.5	4.5	70.6	No erosion.
(2.) Filtered and disinfected water, 1.2 p.p.m. CO_3 alkalinity	Alkaline.	16.3	42.6	....	2.0	2.5	7.4	93.6	No erosion.
(3.) Same as (2) with addition of lime to obtain 2.4 p.p.m. of CO_3 alkalinity	Alkaline.	17.3	45.3	....	1.0	1.7	7.9	106.0	No erosion.
(4.) Same as (2) with addition of lime to obtain 4.8 p.p.m. of CO_3 alkalinity	Alkaline.	19.3	47.9	....	2.0	1.5	8.6^{+}	111.5	No erosion.
(5.) Same as (2) with addition of soda ash to obtain 2.4 p.p.m. of CO_3 alkalinity	Alkaline.	20.4	43.9	....	1.2	2.0	8.0	98.1	No erosion.
(6.) Same as (2) with addition of soda ash to obtain 4.8 p.pm. of CO_3 alkalinity	Alkaline.	23.1	45.3	....	1.8	1.5	8.6^{++}	107.0	No erosion.
(7.) Filtered and disinfected water from Mt. Hope Purification Plant	Alkaline.	40.8	43.9	2.6	1.5	1.2	7.2	98.1	No erosion.
Miraflores Purification Plant:									
(8.) Filtered water	Alkaline.	52.0	53.2	3.8	1.5	2.5	7.1	117.0	No erosion.
(9.) Filtered water after disinfection	Alkaline.	52.0	53.2	4.2	1.5	2.0	7.1	121.3	No erosion.
(10.) Filtered and disinfected water from wash-water tank	Alkaline.	52.0	53.2	3.8	1.5	2.0	7.2	121.3	No erosion.
(11.) Water supply of Cartago, Costa Rica	Alkaline.	65.3	61.4	19.0	1.8	3.2	7.4	146.1	No erosion.
(12.) Water from Thermal Spring, Cartago, Costa Rica	Alkaline.	885.0	468.5	132.0	1.2	1.5	7.3	2948.7	No erosion.
(13.) Water supply of San José, Costa Rica	Alkaline.	57.1	54.6	5.8	1.8	1.5	7.4	107.4	No erosion.
(14.) Water supply of Port Limón, Costa Rica	Alkaline.	88.8	86.6	0.8	1.5	1.0	7.7	171.8	No erosion.
(15.) Santa Ana mineral water, Costa Rica	Alkaline.	829.8	516.0	720.0	1.0	2.1	7.1	2465.0	No erosion.
(16.) Mineral water from Miraflores dump, Canal Zone	Alkaline.	523.6	1060	4.4	2.0	2.5	7.5	4292.5	No erosion.
(17.) Distilled water	Neutral.	1.5	4.0	....	185.0	500.	4.8	1.7	Erosion.

Notes: Residual Cl: Sample 2 = 0.01 p.p.m.; Sample 7 = 0.01 p.p.m.; Sample 9 = 0.24 p.p.m.; which disappeared in one hour thirty-five minutes; Sample 10 = 0.01 p.p.m.
Dissolved Oxygen: Sample 9 = 7.3 p.p.m.; 92.2 per cent. sat. Sample 10 = 7.4 p.p.m.; 93.4 per cent. sat. All erosions noted after samples stood seven days.
Average temperature of closet in which test tubes were stored was 26.3 degrees Cent.
Phenol red used as indicator for Ph determinations above 6.6; methyl red for those below 6.0.
The pieces of lead used in these experiments measured 1 x ½ x 3/32 in.

Mr. Gage's remarks show us in a striking manner that we must not consider our work as being satisfactorily finished by the delivery to the public of a clear, colorless water, free from disease germs. We must bear in mind that other influences, in addition to those due to bacteria, are at work to produce ill health. Outside of the New England States I venture to say that very little work has been done or is being done in the United States by chemists, either in the laboratories of water works or of state departments of health, to determine the corrosive properties of water supplies on lead pipe.

The cases which Mr. Gage cites to show the connection between rheumatism and the consumption of lead-carrying waters are so illuminating that one cannot pass lightly over them or eliminate them as freak cases. Mr. Gage can well afford to be called a crank when his interest in this subject has cleared up various cases of puzzling ailments.

Fully as interesting as the cures effected is the assistance which Mr. Gage is rendering to the physicians of Rhode Island. This is a public-health measure of great importance, and should be adopted in health department laboratories, both in cities and states.

After mailing this discussion to the Secretary of the Association, I received an abstract of a recent paper read by James E. Reade before the Institution of Civil Engineers of Ireland, from which the following two paragraphs were taken:

"Special attention should be directed by those responsible for public health to the existence of what may be called disguised or obscured plumbism, so that whenever a lowering of the general standard of health is observed, consideration should be given to the part played by the domestic water supply, as at least a possible contributory cause."

"The usual water analysis gives no indication of the plumbo-solvent or erosive character of the samples examined. Possibly water analysts might consider the feasibility of supplementing their reports in this respect. There are certain well-known channels of investigations regarding the sanitary quality of a water supply in which inquiry is always directed. It will probably be most convenient, at any rate in the case of a proposed new water supply, to carry on the quest for plumbo-activity simultaneously. But in all cases the objective will be to determine whether the water in question possesses permanently or periodically, or whether any circumstances exist which would justify a suspicion that it may at any time become capable of acquiring, that most undesirable property."

THE FLUSH VALVE.

BY GORDON M. FAIR.*

[*Read February 9, 1921.*]

The recent report of the Special Plumbing Board of the Massachusetts Department of Public Health calls to the attention of architects, engineers, and plumbers the important change made during the past few years in the flushing of water-closets by the introduction of the flush valve. The use of this device to replace the flushing of closets from cisterns that receive their supply of water at a slow rate through a ball cock should be of especial interest to water-works engineers because the flush valve is operated in closer connection with the water-distributing system and makes demands on it that have not had to be coped with in the past.

The flush valve, which is sometimes called a "flushometer," is an automatic, quick-opening and slow-closing valve, operated by means of a lever or a push-button and connected directly to the water-supply system. Three factors in its use are of interest:

1. The sanitary factor.
2. The economic factor.
3. The hydraulic factor.

Of these the hydraulic factor is by far the most important. In formulating regulations relative to the use of flush valves, however, the other two should not be neglected.

The Sanitary Factor.

Flush valves should be placed with care if the contamination of the water supply as a result of siphoning into the distributing system polluted water standing in the closet is to be prevented. Authorities that have formulated regulations for installing flush valves have decreed that the valve must be situated above the closet seat, in order to break, at the end of each flush, the hydraulic connection between water supply and closet contents. Even when the valve is placed in accordance with this ruling it may under certain conditions become possible to contaminate the water in the distributing system. If, for example, the closet were clogged to such an extent that the water level were high enough to seal the rim from which the bowl is flushed, or if in the case of a siphon jet closet the rim had become clogged by impurities carried in the water, it might be

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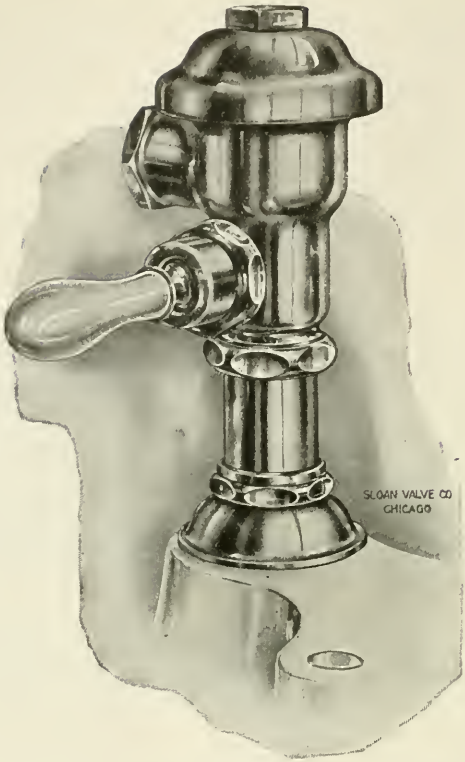

SLOAN VALVE CO
CHICAGO

FIG. 1.

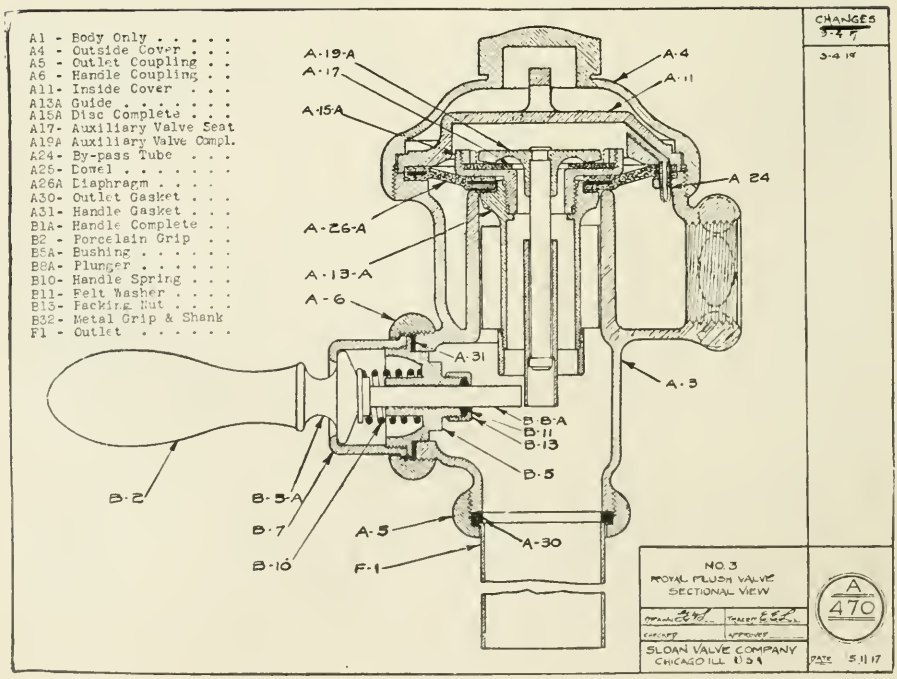

A1 - Body Only
A4 - Outside Cover
A5 - Outlet Coupling
A6 - Handle Coupling
A11- Inside Cover
A13A Guide
A15A Disc Complete
A17- Auxiliary Valve Seat
A19A Auxiliary Valve Compl.
A24- By-pass Tube
A26- Dowel
A26A Diaphragm
A30- Outlet Gasket
A31- Handle Gasket
B1A- Handle Complete
B2 - Porcelain Grip
B5A- Bushing
B8A- Plunger
B10- Handle Spring
B11- Felt Washer
B13- Packing Nut
B32- Metal Grip & Shank
F1 - Outlet
A-19-A
A-17
A-15A
A-26-A
A-13-A
A-6
A-31
A-4
A-11
A 24
A-3
B-8-A
B-11
B-13
B-5
B-2
B-5-A
B-7
B-10
A-5
F-1
A-30
CHANGES
3-4 11
NO. 3
ROYAL FLUSH VALVE
SECTIONAL VIEW
CHICAGO
APPROVED
SLOAN VALVE COMPANY
CHICAGO ILL. U.S.A.
DATE 5.11.17
A
470

FIG. 2.

possible by operating a fixture on a lower floor to siphon the contents from the closet into the distributing system. The conditions necessary to bring about such an occurrence may seem strange and extraordinary, but they constitute a potential danger and should not be neglected in the design of the distributing system. In the light of these possibilities, the cistern or tank system seems safer; in other sanitary respects, however, the flush valve has advantages over the tank system. For example, the flush valve is again ready for use immediately after the flush is completed, whereas several minutes elapse before the cistern is filled. The valve, too, is more substantial in construction and less liable to get out of order. These advantages should result in the avoidance of the unsightly conditions often encountered when one flush is not sufficient to empty the closet or when the flushing device is out of repair.

The Economic Factor.

When the writer first undertook the study of the flush valve, he believed that both the first cost and the cost of operation of flushing devices might be in favor of the flush valve. As shown below, however, the first cost is influenced by hydraulic considerations to such an extent that the installing of flush valves is usually quite as expensive and in some cases even more expensive than the installing of cisterns, not because of the difference in cost of the flushing device proper but because of the difference in the cost of the piping necessary to supply them with water. The cost of operating flushing devices, on the other hand, is not dependent upon their hydraulic properties but upon the construction of the closet which they are supposed to flush. Each closet, it seems, has an optimum rate and amount of flush which may vary from 3½ gal. in ten seconds, or a rate of 21 gal. per minute, to 3 gal. in four seconds, or a rate of 45 gal. per minute. The total delivery of a flush lies usually between 3 and 4 gal., with an average rate of about 25 gal. per minute. It is claimed that some closets can be flushed with as little as 1½ gal. in one second. Even if this be admitted, it is easily seen that unless there is a large and continuous discharge of water from other fixtures a volume of 1½ gal. of water is not sufficient to carry the waste material with adequate flushing through soil stack and house drain to the sewer. Plumbing regulations, therefore, usually prescribe a minimum flush of 3 to 6 gal. The rate of flow of 1½ gal. in one second, or 90 gal. per minute, is also excessively high and requires a very large and uneconomical piping system. It is therefore improbable that water will be conserved by using flush valves and high rates of flow through long lines of pipe instead of cisterns that are filled slowly and discharge rapidly through a relatively short line of pipe.

The cost of keeping the flush valve in repair, however, should be small, because the mechanism of the flush valve is simple and strong. There is little chance of the valve getting out of order; the only part that

requires attention is the by-pass, which is narrow and easily clogged with foreign matter or rust. Red lead or other jointing material, used in connecting up the original piping system or in making repairs, is often a nuisance in this respect and makes it necessary to flush the system thoroughly before attaching the valve. In order to facilitate inspection of the valve, the device is usually equipped with a stop valve which permits the water supply to be cut off at the fixture. In some designs this stop valve also serves to regulate the quantity of water passing through the valve by being adjusted to throttle down the operating pressure to a desired value.

The Hydraulic Factor.

As stated above, the hydraulic factor of the flush-valve problem is by far the most important one. It may be considered under two headings:

1. The hydraulics of the flush valve proper.
2. The influence of the use of the flush valve on the hydraulics of the water-distributing system.

The hydraulic properties of the flush valve itself are established by the design. Six different types of valves have come to the writer's attention.

1. The water-operated diaphragm-type, fully-automatic valve without regulating mechanism.
2. The water-operated plunger-type, fully-automatic valve without regulating mechanism.
3. The water-operated plunger-type, fully-automatic valve with regulating mechanism.
4. The water-operated plunger-type, semi-automatic valve with regulating mechanism.
5. The water-operated plunger-type, semi-automatic valve without regulating mechanism.
6. The air-operated plunger-type, semi-automatic valve with regulating mechanism.

A fully automatic valve is one that discharges a constant amount of water and closes even when an attempt is made to prolong the flush by continuing to press down the lever or push-button that activates the mechanism, whereas a semi-automatic valve continues to discharge water until the lever or push-button is released.

A water-operated valve provided with a regulating mechanism is one in which the time of closing can be controlled by changing the size of the by-pass leading from the pressure side of the valve to the chamber beyond the piston head or diaphragm. When the valve is put into operation a jet or stream of water passes through this aperture into the chamber, gradually builds up sufficient pressure in the same, and forces the piston head or diaphragm upon its seat. In the fully automatic valve this

regulating mechanism controls the length of flush; in the semi-automatic valve it controls merely the rapidity of closing or the "refill" after the lever or button has been released.

An air-operated valve provided with a regulating mechanism finally is one in which the time of closing can be controlled by regulating the size of an aperture that permits air to escape from a chamber into which it is sucked when the valve is put into operation.

At the suggestion of Prof. George C. Whipple and through the courtesy of flush-valve manufacturers, seven different makes of valves were tested by Mr. Stanley T. Barker and the writer for the following properties, in the Laboratory of Sanitary Engineering of Harvard University:

1. Quantity of water delivered at various pressures
   (*a*) for flushing the closet
   (*b*) for refilling the closet with water after the flush is completed. (This quantity is known as the "refill.")
2. Rate of flow of water at various pressures.
3. Water hammer.

The results of these tests are shown in Tables 1 to 8.

TABLE 1.

VALVE A.

1-IN. DIAPHRAGM-TYPE, WATER-OPERATED, FULLY-AUTOMATIC CLOSING DEVICE WITHOUT REGULATING MECHANISM.

Operating Pressure. Lbs. per Sq. In.	Flush. Gal.	Time. Sec.	Re-fill. Gal.	Time. Sec.	Total Flow. Gal.	Time. Sec.	Rate of Flush. G.P.M.
5	2.6	9.5	.2	4.0	2.8	13.5	16.4
10	2.9	8.0	.1	3.0	3.0	11.0	21.7
15	2.9	6.5	.1	2.5	3.0	9.0	26.8
20	3.0	6.0	.1	2.5	3.1	8.5	30.0
25	3.0	5.0	.1	2.0	3.1	7.0	36.0
30	3.0	4.5	.1	2.0	3.1	6.5	40.0
35	3.0	4.5	.1	2.0	3.1	6.5	40.0
40	3.0	4.0	.1	2.0	3.1	6.0	45.0
45	2.9	4.0	.1	2.0	3.0	6.0	43.5
50	2.9	4.0	.1	2.0	3.0	6.0	43.5
55	2.9	4.0	.1	2.0	3.0	6.0	43.5

TABLE 2.

Valve B.

1-in. Plunger-Type, Water-Operated, Fully-Automatic Closing Device.

Regulating mechanism set to give maximum discharge at each pressure.

Operating Pressure. Lbs. per Sq. In.	Flush. Gal.	Time. Sec.	Re-fill. Gal.	Time. Sec.	Total Flow. Gal.	Time. Sec.	Rate of Flush. G.P.M.
5	4.9	13.0	1.3	22.0	6.2	25.0	22.6
10	4.0	7.5	0.7	10.5	4.7	18.0	32.0
15	2.9	5.0	0.4	5.5	3.3	10.5	34.7
20	1.7	3.0	0.2	3.0	1.9	6.0	34.0
25	0.6	2.0	0.1	1.0	0.7	3.0	18.0

TABLE 3.

Valve C.

1-in. Plunger-Type, Water-Operated Closing Device (Fully-Automatic only at Moderate to High Pressures) Without Regulating Mechanism.

Operating device held open for 1 second at low pressure.

Operating Pressure. Lbs. per Sq. In.	Flush. Gal.	Time. Sec.	Re-fill. Gal.	Time. Sec.	Total Flow. Gal.	Time. Sec.	Rate of Flush. G.P.M.
5	2.4	5.0	0.1	3.0	2.5	8.0	28.8
10	2.2	3.0	0.1	2.0	2.3	5.0	44.0
15	1.9	2.5	0.1	2.0	2.0	4.5	45.6
20	1.7	2.0	0.1	2.0	1.8	4.0	51.0
25	1.6	2.0	0.1	1.5	1.7	3.5	48.0
30	1.5	1.5	0.1	1.5	1.6	3.0	60.0
35	1.4	1.5	0.1	1.5	1.5	3.0	56.0
40	1.4	1.5	0.1	1.5	1.5	3.0	56.0
45	1.4	1.5	0.1	1.5	1.5	3.0	56.0
50	1.4	1.5	0.1	1.5	1.5	3.0	56.0

TABLE 4.

VALVE D.

1¼-IN. PLUNGER-TYPE, AIR-OPERATED, SEMI-AUTOMATIC CLOSING DEVICE.

Regulating mechanism set to give maximum discharge (screw in 9½ turns) and minimum discharge (screw in 3 turns) respectively.

Operating Pressure. Lbs. per Sq. In.	Rate of Flush before Releasing Handle. G.P.M.	Discharge after Releasing Handle.		Time of Discharge. Sec.	
		Max. Gal.	Min. Gal.	9½ Turns.	3 Turns.
5	25.2	12.6	0.1	77	1.0
10	36.0	12.2	0.1	69	1.0
15	46.8	11.9	0.1	63	1.0
20	55.5	11.7	0.1	60	1.0
25	61.9	11.6	0.1	56	1.0
30	67.0	11.5	0.1	54	1.0
35	72.0	11.4	0.1	52	1.0
40	74.3	11.4	0.1	51	1.0
45	77.9	11.3	0.1	50	1.0
50	80.0	11.3	0.1	50	1.0
55	81.5	11.3	0.1	50	1.0

TABLE 5.

VALVE E.

1¼-IN. PLUNGER-TYPE, SEMI-AUTOMATIC CLOSING DEVICE WITHOUT REGULATING MECHANISM.

(Operating device held open for 1 second.)

Operating Pressure. Lbs. per Sq. In.	Flush. Gal.	Time. Sec.	Re-fill. Gal.	Time. Sec.	Total Flow. Gal.	Time. Sec.	Rate of Flush. G.P.M.
5	3.7	5.5	0.6	6.0	4.3	11.5	40.4
10	3.8	5.0	0.6	5.0	4.4	10.0	45.6
15	4.0	4.0	0.6	5.0	4.6	9.0	60.0
20	4.1	3.5	0.5	5.0	4.6	8.5	70.3*
25	4.1	3.5	0.5	4.0	4.6	7.5	70.3
30	4.2	3.0	0.5	4.0	4.7	7.0	84.0
35	4.2	3.0	0.5	3.5	4.7	6.5	84.0
40	4.2	3.0	0.4	3.0	4.6	6.0	84.0
45	4.3	3.0	0.4	2.5	4.6	5.5	86.0
50	4.3	3.0	0.4	2.5	4.6	5.5	86.0

TABLE 6.

VALVE F.

1¼-IN. PLUNGER-TYPE, SEMI-AUTOMATIC CLOSING DEVICE WITH (A) REGULATING MECHANISM SET TO GIVE MAXIMUM DISCHARGE (SCREW OPENED ½ TURN).

Operating device held open for 1 second.

Operating Pressure. Lbs. per Sq. In.	Flush. Gal.	Time. Sec.	Re-fill. Gal.	Time. Sec.	Total Flow. Gal.	Time. Sec.	Rate of Flush. G.P.M.
5	4.4	8.0	0.2	4.0	4.6	12.0	33.0
10	4.6	6.5	0.2	2.0	4.8	8.5	42.5
15	4.6	5.5	0.2	2.0	4.8	7.5	50.2
20	4.7	4.5	0.2	1.5	4.9	6.0	62.7
25	4.7	4.0	0.2	1.5	4.9	5.5	70.5
30	4.7	4.0	0.1	1.0	4.8	5.0	70.5
35	4.7	3.5	0.1	1.0	4.8	4.5	80.6
40	4.7	3.5	0.1	1.0	4.8	4.5	80.6
45	4.7	3.5	0.1	1.0	4.8	4.5	80.6
50	4.7	3.5	0.1	1.0	4.8	4.5	80.6
55	4.7	3.0	0.1	1.0	4.8	4.0	94.0

(*B*) REGULATING MECHANISM SET TO GIVE MINIMUM DISCHARGE (SCREW REMOVED).

5	1.6	4.0	0.1	1.5	1.7	5.5	24.0
10	1.9	3.0	0.1	1.0	2.0	4.0	38.0
15	2.0	2.0	0.1	1.0	2.1	3.0	60.0
20	2.1	2.0	0.0	1.0	2.1	2.0	63.0
25	2.1	2.0	0.0	1.0	2.1	2.0	63.0
30	2.2	2.0	0.0	1.0	2.2	2.0	66.0
35	2.2	2.0	0.0	1.0	2.2	2.0	66.0
40	2.2	2.0	0.0	1.0	2.2	2.0	66.0
45	2.2	2.0	0.0	1.0	2.2	2.0	66.0
50	2.2	2.0	0.0	1.0	2.2	2.0	66.0

TABLE 7.

VALVE G.

$1\frac{1}{2}$-IN. PLUNGER-TYPE, SEMI-AUTOMATIC CLOSING DEVICE WITH (*A*) REGULATING MECHANISM SET TO GIVE MAXIMUM DISCHARGE (SCREW OPENED $\frac{1}{4}$ TURN).

Operating device held open for 1 second.

Operating Pressure. Lbs. per Sq. In.	Flush. Gal.	Time. Sec.	Re-fill. Gal.	Time. Sec.	Total Flow. Gal.	Time. Sec.	Rate of Flush. G.P.M.
5	10.5	13.0	1.1	7.0	11.6	20.0	48.5
10	10.6	8.0	.9	5.0	11.5	13.0	79.5
15	10.7	7.0	.8	5.0	11.5	11.0	91.8
20	10.8	6.0	.8	3.5	11.6	9.5	108.0
25	10.8	5.5	.6	3.0	11.4	8.5	118.0
30	10.9	5.0	.6	3.0	11.5	8.0	131.0
(*B*) REGULATING MECHANISM SET TO GIVE MINIMUM DISCHARGE (SCREW REMOVED).							
10	4.7	4.0	.2	3.0	4.9	7.0	70.5
15	5.0	4.0	.2	2.0	5.2	6.0	75.0
20	5.2	4.0	.2	1.5	5.4	5.5	78.0
25	5.3	3.5	.2	1.5	5.5	5.0	90.8
30	5.4	3.0	.2	1.5	5.6	4.5	108.0
35	5.5	3.0	.2	1.0	5.7	4.0	108.0

TABLE 8.

WATER HAMMER CAUSED BY FLUSH VALVES.

Type of Valve.	Remarks.
A	Very little water hammer at all pressures.
B	Considerable water hammer at high pressures.
C	Very little water hammer at all pressures.
D	Water hammer depends upon adjustment of regulating mechanism.
E	Considerable water hammer at higher pressures.
F	Water hammer depends upon adjustment of regulating mechanism.
G	Water hammer depends upon adjustment of regulating mechanism.

A study of these tables leads to the following conclusions. Of the fully automatic valves only those valves (A and C) that were not provided with a regulating mechanism were successful. It is not known what was the matter with the valve in which the time of closing could be regulated (Valve B), and no claim is made that it is representative of its class. Valve C, which like Valve A delivered fairly constant quantities of water at all pressures and at quite uniform rates, seems to have been designed for the flushing of urinals, because the volume of flush is hardly sufficient for water-closets. Both of these valves closed slowly even under high pressures, as evidenced by the absence of water hammer.

Valve D, which is air-operated, and the water-operated Valves F and G are semi-automatic. By adjusting the regulating mechanism controlling the closing rate of these valves and by setting the stop valve in the proper position, it is possible to obtain from them practically any desired quantity and rate of flush, providing the length of time that the lever or button is pressed is accurately gaged. This constitutes a considerable advantage over the fully automatic valves. On the other hand, the operating mechanism of these valves may be kept open *ad libitum*, a condition that may entail either a considerable waste of water or an unsatisfactory flush, whenever the length of time that the lever or button is pressed is not accurately gaged by the user.

Excessive water hammer can be avoided in these valves by a proper regulation of their time of closing.

Valve E, the semi-automatic valve without a regulating mechanism, finally has the objection of giving rise to a considerable water hammer at the higher pressures. This, however, may be cut down by decreasing the pressure through a proper setting of the stop valve. The discharge volume per unit of time of operation is evidently quite constant at varying pressures, so that any desired flush may be obtained from this valve if the time of operation is well gaged, a condition that is subject to the same criticism as above. Unfortunately, lack of time did not permit an investigation of the means used by plumbers to avoid water hammer in pipe systems supplying water at the high velocities often employed in flush-valve installations. Theoretically, however, the common practice of providing air chambers at the end of the line is open to criticism. These air chambers are generally merely extensions of the supply pipe beyond the last fixture, and no provision is made to replace the air absorbed by the water or lost in other ways. Of course it is possible to place a gate valve at the entrance to the air chamber and to provide the chamber with two pet cocks. By closing the gate valve and opening the pet cocks the air cushion can then be re-established. An arrangement such as this needs attention from time to time, and is, therefore, subject to the objection that it brings in the human factor into an otherwise mechanically automatic problem. It is the writer's opinion, however, that, by a proper

setting of flush valve and stopcock, water hammer can be decreased more efficiently than by any other means.

It is evident that fixtures working at as high rates of flow as flush valves require a well-planned arrangement and size of supply piping to insure successful operation. At the present time there are three systems in common use for piping water to flush valves.

1. The direct-pressure system.
2. The gravity tank system.
3. The pressure-tank system

In the direct-pressure system the water is taken either from the service connection to the street main or from a separate connection made specially for this purpose and independent of all other fixtures in the building. It is a scheme that can be made to work successfully wherever it is possible to secure a connection to the water main that is large enough to permit employing pipe sizes proportioned in accordance with the demands of the flushing device. However, it is interesting to note that the connections specified by water departments are generally too small. A $\frac{3}{4}$-in. service pipe, for example, can deliver water to a flush valve at a rate of about 15 g.p.m. provided a city pressure of 40 lb. per sq. in. is available and the length of piping, including the customary allowances for bends, does not exceed 100 ft. As against this, a single flush valve (see Tables 1-7) discharges water at a rate of 25 to 40 g.p.m. and thus consumes all the water that under the conditions assumed can be conveyed to it in a one-in. pipe, providing the same does not supply any other fixtures. This fact usually excludes to all but the large consumers such as hotels, office buildings, and school houses the use of flush valves on the direct-pressure system. To be successful, furthermore, systems supplying valves for which the discharge rate and quantity vary with the water pressure must be equipped with a pressure regulator or other device that will keep the pressure constant. Only where high and constant city pressures are available may the required size of piping become small and therefore economical enough for small consumers. The direct-pressure system may then be used to advantage in communities in which the sevices are not metered. This proviso must be made because the smallest size meter that can deliver water to a single flush valve at an average rate of 30 g.p.m. with a loss of head of about 5 lb., for example, is a $1\frac{1}{4}$-in. meter. At this rate, two flush valves would require a 2-in. instrument. Meters of these sizes are, of course, absurdly large for services that could normally be gaged by a $\frac{5}{8}$-in. instrument. Even if large meters could be installed economically, it must be remembered that the amount of unregistered water, which for a given low flow is greater for a large meter than a small one, would increase to the disadvantage of the water department's revenue.

The writer may seem to discourage the use of flush valves on direct-pressure systems for small consumers, but he does not want to give the impression that this system cannot be employed successfully by large

consumers whose large service connections are equipped with large meters. The gravity-tank system and the pressure-tank system avoid some of the objections to the use of flush valves in connection with small systems. The gravity-tank system employs an open tank placed at as high a point as possible in the building. Water is supplied to it at a slow rate through a ball cock or some other device that will keep the water level of the tank at some constant height. From the tank, piping properly proportioned to secure the effective operation of the flush valve leads to the closet. The elevation of the tank is usually such as to give a pressure of at least 5 or 10 lb. at the fixture. The required size of tank varies with local conditions. For a school or factory, for example, in which a large number of fixtures is used during a comparatively short interval of time an allowance of 6 gal. for each water-closet and two gal. for each urinal is sometimes recommended. This corresponds to a per capita allowance of 0.3 to 0.5 gal., and varies with the size of the establishment, a smaller per capita allowance being made with increasing number of people. A minimum tank capacity of 25 gal. is desirable, and it is of course assumed that the larger the tank the larger will be the ball cock controlling the water level.

Unfortunately, open tanks are apt to accumulate dust, rust, organic growths, and other foreign matter which may clog the by-pass of the flush valve. Tank and ball cock also must be protected against freezing and otherwise need attention from time to time. The work connected with the care of one of these tanks may seem small, but this circumstance makes efficient supervision perhaps all the harder.

For these reasons pressure tanks that can be erected in any convenient part of the building where they are protected from the cold are sometimes substituted for the gravity tanks. In the pressure-tank system the service pipe entering the building usually divides in the cellar; one branch leads up to the pressure tank and the flush valves, and the other branch supplies the remaining fixtures. A check valve is inserted in the flush-valve piping at the juncture with the main supply pipe. The only disadvantage of this system compared with the gravity supply lies in the operation of the valves under a falling head. Valves that discharge the same quantity of water under all pressures here find their most effective use. Otherwise the pressure-tank system shares with the gravity-tank system most of the advantages over the direct-pressure system. Its influence on meterage, however, is perhaps open to objection.

The size of piping necessary to feed various numbers of flush valves can readily be computed by an engineer, providing he knows the city pressure at the building. It is not as easily done by a plumber. For this reason manufacturers have evolved various schemes for presenting the necessary information in a simple way. Each scheme, of course, takes into account the hydraulic characteristics of the particular valve, and it is hardly possible to lay down any general rules that will suit all valves on the market. The necessary data, however, could be presented in a

table showing the amount of water delivered by pipes of various size and of different length discharging under a pressure of at least 5 to 10 lb. into the flush valve. Such tables are commonly found in plumbing catalogues, and there is no necessity for reprinting in this paper a table such as the author has in mind.

SUMMARY.

In conclusion, the points of this paper that should interest water-works engineers most may be summarized as follows:

1. Unless carefully placed in a well-designed distributing system the use of the flush valve may result in contamination of the water supply.
2. There is little reason to believe that water will be conserved by the use of the flush valve.
3. The installing of flush valves is only economical in large buildings.
4. The effect of the use of flush valves on water meterage and water hammer needs investigation.
5. The choice of the type of distributing system should be made only after the type of flush valve that will be used has been determined.

A consideration of this summary suggests to the writer another point that should be of interest to water-works men not only in connection with the use of the flush valve but in connection with the plumbing of buildings as a whole. This point is taken up in the report of the Special Plumbing Board of the Massachusetts Department of Public Health, on page 54 and following. The present status of the distribution of water within buildings is here called to the attention of engineers, who after reading this section of the report perhaps will agree with the statement that "there are good reasons why a sanitary code should include the water-distribution systems as well as the drainage system."

DISCUSSION.

MR. FRANK E. MERRILL.* I should like to ask the gentleman if he has any data in regard to the amount of water hammer caused by the ordinary flush valve.

MR. FAIR. That all depends upon the setting and how the flush valve is arranged. There is no reason why the flush valve should give any water hammer at all. If badly arranged, of course, there will be water hammer. And the amount of water hammer varies greatly with the flush valve used. There are certain flush valves that give high water hammer if the pipe is not well arranged and the stop-valve well set. By using the stop-valve you can cut down the pressure so that the water hammer will be decreased.

* Water Commissioner, Somerville, Mass.

Mr. A. W. F. Brown.* I think the use of flush valves is very detrimental to the water works. There has been severe water hammer where they were installed by plumbers who are A1, so far as I know. I had a water-gage knocked out in my office and felt a distinct tremor in the floor. There are three valves, supplied by a 2-in. pipe, running into a 1-in. with 80 lb. pressure behind it. I do not see any advantage over the tank closet, which will operate, if it gets water, within a reasonable time. The extra cost over the ordinary service is perhaps over a hundred per cent, because when they come into general use, and are used by the hundreds or thousands, it means that the 1-in. and $\frac{3}{4}$-in. services must be cleaned out and replaced by larger services.

Mr. G. Wilbur Thompson.† I have obviated water hammer in several cases by putting in a large air chamber, perhaps 4 or 5 ft. long, made out of 2- or $2\frac{1}{2}$-in. pipe, close by the meter, and also put a drip cock, or a little pet cock, right in the top. In case the action is something like an hydraulic ram, the pressure of the water will force out the air. In this same way the water will fill this chamber, but by putting in a draw-off cock below, and the little vent at the top, you can run the water out very quickly.

Mr. Brown. I have tried it, and in about a week or two there won't be any air there; the water will take up the air under a heavy pressure.

Mr. Thompson. That may be true; but if it was absolutely tight it ought to last longer than that, because an hydraulic ram will go sometimes for months before it exhausts all the air in the chamber.

Mr. David I. Heffernan.‡ I had one of those installations on a large service. In regard to small services, 1 in. in size, I have seen installations of the flushometer which I thought was a very good scheme. That was to place a pressure tank over the closet itself, over the flushometer. The one I am speaking of was made out of wrought-iron pipe. This flushing device works satisfactorily by having what we call the utility tank to resist any pressure. It holds about 3 gal. above the amount of water required to operate the flushometer. That was on an inch service. In this house are four or five bathrooms, and it gives perfect satisfaction.

Mr. Thompson. It seems to me if the tank only holds 3 gal. and is under pressure, that when the water comes down to the closet, the tank is refilling just as fast. When the valve closes you have got no air check there or cushion for that to rebound on, whereas in an air chamber you would have.

Mr. Heffernan. Yes, true enough.

However, it is a homemade affair and gives perfect satisfaction.

* Registrar and Superintendent Water Works, Fitchburg, Mass.

† President of Mass. Association of Master Plumbers.

‡ Superintendent Water Works, Milton, Mass.

REPORT OF COMMITTEE ON RAINFALL AND RUN-OFF MEASUREMENTS.

March 25, 1921.

The New England Water Works Association,

715 Tremont Temple, Boston, Mass.

Gentlemen, — This committee was appointed in December, 1918, "to consider the collection and standardization of rainfall and run-off measurements." Mr. William T. Barnes was chairman of the committee until March, 1920, when he resigned, owing to his removal from New England, and was succeeded by the present chairman.

Three meetings of the committee were held in 1918 and 1919, one jointly with the Boston Society of Civil Engineers' Committee on Run-off. At these meetings a program of work to be undertaken by the committee was definitely outlined, and this program has been stated in the progress report of the committee by Mr. Barnes, rendered September 22, 1919.

During the present year the work done by the committee has consisted merely in carrying out this program in the matter of collecting and preparing for publication certain available records of stream flow and rainfall. The character of the records to be included in its report, and the proper form of publication of same, was given extended consideration by the committee, and the following conclusions were reached:

(1) It was deemed advisable to bring down to date such of the reports of the yield of smaller New England drainage basins published in the report of the Committee on Yield in 1914 as are available.

(2) To collect and publish such additional records of yield of similar water-works drainage basins in New England and New York as are available.

(3) Inasmuch as they are generally available in printed form, it was deemed advisable not to include records for streams which are published in the annual water supply papers of the U. S. Geological Survey.

(4) Each published record to be accompanied by as complete a statement as possible of the conditions affecting the accuracy of the record and the yield of the drainage basin.

(5) It was decided to follow generally the form of publication used by the committee of 1914 in the preparation of data, both for the sake of comparison of the later records with those formerly published, and for the reason that many water-works superintendents use substantially the same form in the publication of run-off data in their annual reports. In this

connection it was decided, after full discussion, to present the data in the form of monthly values by calendar years, leaving the person desiring to apply the data to re-arrange it in water or hydrologic years, according to his own liking.

(6) The committee deems it its duty to compile at present for publication, in such a form as to give a permanent record, fundamental or original data only. The committee has not, therefore, undertaken an analysis of the records or deductions therefrom.

In the report of the Committee on Yield of Drainage Areas in 1914, columns were included in the table of run-off, showing the estimated yield per square mile of land area, exclusive of swamps or water surfaces. The present committee has omitted these deductions, but has attempted to furnish data relative to the swamps and water surface areas, which may be used as a basis of correction of the records in any manner which may be desirable. Inasmuch as the apparent water losses are the principal factor, aside from rainfall, which determines the amount of run-off, and, further, since the apparent water losses are fundamental data in the sense that they are deducible directly from the measured precipitation and run-off, a column has been added to the run-off tables containing apparent water losses. It is to be understood that "apparent water losses" are merely the difference between the measured precipitation and the measured yield, and are not necessarily the true or actual water losses for any short interval of time, since the apparent water losses include the effect of gain or loss of storage from ground water, soil, lakes, swamps, marshes, stream channels, and reservoirs. The matter of attempting to correct the apparent water losses for these effects has not been undertaken. Inasmuch as water losses are generally found to be more nearly constant over large areas than either precipitation or run-off, and the use of water losses as a factor in estimating or extending stream-flow records is apparently increasing, it was decided to include them in the tables.

Following its policy of not in general attempting to analyze the data presented, no effort has been made to estimate the mean annual precipitation on drainage basins for which the run-off is given. If, however, the mean precipitation on the drainage basin was furnished with the data from the original source, then it has been included with the data for publication.

Wherever possible, a statement of the names and locations and weights of rainfall records used in estimating the mean precipitation are given. It is to be understood, however, that the data of mean precipitation on different drainage basins are offered merely for what they are worth, and neither the committee nor the Association is directly responsible for such figures as are presented.

In a region of diversified topographic and geologic conditions, such as New England, differences in run-off or yield of adjacent drainage basins, or different parts of the same basin, especially in the case of smaller areas, may be due not to differences in rainfall or water losses at all, but to water-

shed leakage. A study of the conditions where watershed leakage is likely to occur, and an attempt to formulate rules for its detection, was undertaken by one of the members of the committee, and has been published in the JOURNAL as a contribution to the work of the committee.* Reference is made to this paper for a discussion of conditions affecting probable watershed leakage on some smaller New England drainage basins. In this connection it may be pointed out that Abbott Run, at Pawtucket, R. I., shows apparently a smaller yield in relation to precipitation than the drainage basin of the north branch of the Pawtuxet River. The geology of the Abbott Run drainage basin is complex, and the rocks are often intricately fractured and folded. It has been suggested that the apparent deficiency in yield of Abbott Run may be due to watershed leakage.

In studies of the minimum yield of drainage basins, and the amount of storage required to provide a specified constant flow, the use of daily rather than monthly records of run-off is often desirable. The committee, however, did not feel that in view of the costliness of paper and printing the presentation of the records of rainfall and run-off in a daily form is at present justified. Some of these records in daily form are given in the annual reports of the water-works departments by which the records were maintained. Such reports are commonly issued in limited editions, and as a rule are out of print shortly after their publication. References, however, to daily records, where so published, are included with the data here presented.

In many instances records of rainfall are maintained in conjunction with water-works systems where no records of run-off are kept. Inasmuch as records of rainfall throughout New England down to the end of 1913 have recently been published in the JOURNAL of the New England Water Works Association,† and since the author of this paper has offered to bring these records down to date for publication in the JOURNAL, it was deemed advisable that records of rainfall only compiled by this committee should be turned over to Mr. X. H. Goodnough, for presentation to the Association in conjunction with other records compiled by him.

In connection with this matter, a slight departure from the usual practice in the compilation of rainfall records has been made by the committee, in that, wherever available, the amounts of precipitation and the number of rainfall days in each month have been given in parallel columns. The reason for including the number of rainfall days with the precipitation is that the amount of run-off resulting from a given precipitation varies according to the manner in which the rain falls. A record of the number of rainfall days gives some indication as to whether a given amount of rain fell slowly through a prolonged period of time, or whether it fell rapidly in short heavy storms.

* "Watershed Leakage in Relation to Gravity Water Supplies." Robert E. Horton, JOURNAL N.E.W.W. ASSN., Vol. 33, No. 3, pp. 305–336.

† "Rainfall in New England," by X. H. Goodnough. JOURNAL N.E.W.W. ASSN., Vol. 39, September, 1915; pp. 237–438.

In the course of compilation of rainfall records, it was found that there were some inconsistencies, especially when results of adjacent gages were compared. A detailed study of the method and accuracy of rainfall measurements was made by one of the members of the committee as a contribution to the work of the committee, and has already been published.* The committee has not attempted to eliminate inconsistencies in rainfall records which it has compiled for publication. Illustrations of the variations in the results obtained from adjacent rain gages at certain locations in New England are, however, contained in the paper on Rainfall Measurement above referred to, and suggestions are there given as to methods of determining the probable causes of the variations in specific cases.

It is recommended that the present committee be discharged from further duties, but that in 1921 and each two years thereafter a new committee of three be appointed to compile records for the preceding two years, and that such records be published on as nearly a uniform basis as possible in the JOURNAL of the Association.

It is recommended that water-works superintendents throughout New England generally should see to it that at least one rain gage is maintained in conjunction with each water-works system. This should be a standard 8-in. Weather Bureau gage. In the winter time the depth of precipitation as snow should be measured on level ground, where no drifting occurs, preferably with the use of a snowboard. A sample of the snow should be taken and melted for the determination of the amount of precipitation.

It is recommended that where records of stream flow and precipitation are maintained in conjunction with water-works systems, daily discharges and daily amounts of precipitation should be published each year in the annual report of the superintendent of the water-works system.

In publishing rainfall records, it is desirable that each record should be accompanied by a full description of the rain gage and its location, including its size, height above ground, hour and method of making measurements, — both in the winter and summer, — surrounding topography, direction of slope of ground surface near the gage, and height and character of trees, shrubs, fences or buildings in the vicinity of the gage and their position relative thereto.

Respectfully presented,

ROBERT E. HORTON, *Chairman.*
GEO. A. CARPENTER.
SYDNEY K. CLAPP.
X. H. GOODNOUGH.
H. K. BARROWS.
Committee on Rainfall and Run-off.

* "The Measurement of Rainfall and Snow," by Robert E. Horton. JOURNAL N.E.W.W. ASSN. Vol. 3, No. 1, pp. 14–71.

Hydrologic Description of the Drainage Basin of Hartford Supply Streams above West Hartford, Conn.

Record from — 1910 to 1917. *Years* — Eight.
Discharge obtained by — Weirs and Venturi meters.
Accuracy — Summer, good; winter, good.
Artificial regulation — Complete.
Diversions — None above point of measurement.
Source of records — Reports Hartford Board of Water Commissioners.
Drainage area, square mile — 11.92. Land, 11.22; swamp, 00; water, 0.70.
Drainage area, per cent. — 5.9% water.
Area determined from — U. S. G. S. topographic sheets, Hartford, Meriden, Middletown and Granby sheets.
Orientation — Hill-top areas extending in N-S direction.
Elevation of basin, mean — 460.
How physiographic factors were determined — Topographic maps.
Soil, kinds and location — Sandy loam.
Soil maps — None available.
General depth to ledge rock — 0 to 5 feet.
Ledge rock, kind formation and age — Igneous.
Prevailing dip — 75 ft. *Direction* — E.
Per cent. land area covered by —
Woods — 90. *Kind* — Sparse hardwood, etc.
Crops — little. *Grass* — 10. *Other cover* — 0.

Refs.— Earlier records, June, 1909, to December, 1912, from Journal N.E.W.W. Assn., December, 1914, p. 508. Table shows yield land area corrected for water surface and for gain and loss of storage. See 1914 Journal, p. 145.

Yield of Hartford Streams at West Hartford, Conn.
Drainage Area, 11.92 Sq. Mi.

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile. M.G.D.	Per Sq. Mile. C.F.S.	Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss. In.
1910.							
Jan.	966.7	48.4	2.62	4.06	6.12	4.72	1.40
Feb.	698.4	38.6	2.09	3.24	3.81	3.44	0.37
Mar.	806.1	40.3	2.18	3.38	1.22	4.23	−3.01
Apr.	490.3	25.3	1.37	2.12	4.10	2.47	1.63
May.	194.2	9.5	0.52	0.80	2.57	1.15	1.42
June.	240.3	12.4	0.67	1.04	3.92	1.37	2.55
July.	0.4	0.0	0.00	0.00	2.49	0.25	2.24
Aug.	−4.8	−0.2	−0.01	−0.02	2.52	0.18	2.34
Sept.	21.4	1.1	0.06	0.09	3.14	0.17	2.97
Oct.	−8.1	−0.4	−0.02	−0.03	0.88	0.10	0.78
Nov.	107.4	5.5	0.30	0.46	4.65	0.41	4.24
Dec.	134.2	6.7	0.36	0.56	1.66	0.69	0.97
Year.	*3 646.5*	*187.6*	*0.84*	*1.30*	*37.08*	*19.18*	*17.90*
1911.							
Jan.	254.9	12.7	0.69	1.07	2.61	1.23	1.38
Feb.	242.3	13.3	0.72	1.12	2.36	1.18	1.18
Mar.	759.4	37.9	2.06	3.18	3.75	3.82	−0.07
Apr.	744.6	38.4	2.08	3.22	2.96	3.87	−0.91
May.	80.2	4.1	0.22	0.34	1.65	0.61	1.04
June.	71.1	3.7	0.20	0.31	2.48	0.58	1.90
July.	−3.9	−0.4	−0.01	−0.02	2.81	0.19	2.62
Aug.	64.2	3.2	0.17	0.27	6.06	0.30	5.76
Sept.	67.0	3.5	0.19	0.29	2.24	0.46	1.78
Oct.	960.3	47.9	2.60	4.02	9.83	4.59	5.24
Nov.	621.4	32.1	1.74	2.69	4.17	3.10	1.07
Dec.	501.6	25.0	1.36	2.10	3.19	2.49	0.70
Year.	*4 363.1*	*221.4*	*1.00*	*1.55*	*44.11*	*22.42*	*21.69*

YIELD OF HARTFORD STREAMS. — *Continued.*

Month.	Total Mill. Gal.	Mean C.F.S	Per Sq. Mile.		Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss. In.
			M.G.D.	C.F.S.			
1912.							
Jan.	108.4	5.4	0.29	0.45	1.63	0.51	1.12
Feb.	399.2	21.3	1.16	1.79	2.89	1.95	0.94
Mar.	1 113.0	55.5	3.02	4.66	6.17	5.45	0.72
Apr.	549.8	28.4	1.54	2.38	4.07	2.78	1.29
May	754.8	37.3	2.02	3.13	5.10	3.88	1.22
June	−12.9	−0.7	−0.04	−0.06	0.51	0.30	0.21
July	−17.3	−0.8	−0.05	−0.07	2.12	0.18	1.94
Aug.	−2.5	−0.1	−0.01	−0.01	3.08	0.14	2.94
Sept.	2.5	0.1	0.01	0.01	2.21	0.13	2.08
Oct.	30.6	1.5	0.08	0.13	1.92	0.23	1.69
Nov.	115.8	5.9	0.32	0.50	4.04	0.50	3.54
Dec.	347.9	17.4	0.94	1.46	4.29	1.68	2.61
Year.	*3 389.3*	*171.2*	*0.78*	*1.20*	*38.03*	*17.73*	*20.30*
1913.							
Jan.	533.9	26.7	1.45	2.24	2.56	2.59	−0.03
Feb.	265.5	14.8	0.80	1.24	2.13	1.28	0.85
Mar.	955.8	47.8	2.59	4.01	5.30	4.61	0.69
Apr.	704.0	36.4	1.97	3.05	4.70	3.46	1.24
May	474.5	23.6	1.28	1.98	5.17	2.37	2.80
June	50.9	2.6	0.14	0.22	1.24	0.56	0.68
July	−40.2	−2.0	−0.11	−0.17	1.54	0.10	1.44
Aug.	−0.1	0.0	−0.00	−0.00	3.86	0.10	3.76
Sept.	31.4	1.7	0.09	0.14	3.56	0.25	3.31
Oct.	782.6	39.0	2.12	3.27	9.57	3.72	5.85
Nov.	362.2	18.7	1.01	1.57	2.45	1.86	0.59
Dec.	495.2	24.8	1.34	2.08	3.37	2.44	−0.93
Year.	*4 615.7*	*234.1*	*1.06*	*1.64*	*45.45*	*23.34*	*22.11*

Month.	Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss. In.	Month.	Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss. In.
1914.				1916.			
Jan.	2.95	2.07	0.88	Jan.	1.00	2.59	−1.59
Feb.	1.99	1.26	0.73	Feb.	5.02	3.39	1.63
Mar.	3.60	4.53	−0.93	Mar.	2.21	3.39	−1.18
Apr.	3.70	3.69	0.01	Apr.	2.41	4.46	−2.05
May	2.93	2.48	0.45	May	3.30	1.87	1.43
June	2.07	0.41	1.66	June	4.52	2.42	2.10
July	4.14	0.39	3.75	July	4.42	1.05	3.37
Aug.	1.98	0.25	1.73	Aug.	4.89	0.98	3.91
Sept.	0.29	0.07	0.22	Sept.	4.45	0.48	3.97
Oct.	3.47	0.22	3.25	Oct.	1.53	0.40	1.13
Nov.	2.85	0.62	2.23	Nov.	2.98	0.86	2.12
Dec.	3.71	1.37	2.34	Dec.	2.76	1.49	1.27
Year.	*33.68*	*17.36*	*16.32*	*Year.*	*39.49*	*23.38*	*16.11*
1915.				1917.			
Jan.	6.65	5.16	1.49	Jan.	3.34	2.09	1.25
Feb.	4.08	4.59	−0.51	Feb.	1.71	1.05	0.66
Mar.	0.17	1.12	−0.95	Mar.	3.94	5.91	−1.97
Apr.	1.24	1.60	−0.36	Apr.	2.57	3.16	−0.59
May	2.49	0.88	1.61	May	3.73	2.51	1.22
June	4.13	0.42	3.71	June	4.51	2.09	2.42
July	4.64	0.94	3.70	July	4.13	0.98	3.15
Aug.	9.27	3.68	5.59	Aug.	4.63	0.42	4.21
Sept.	1.75	0.38	1.37	Sept.	1.20	0.25	0.95
Oct.	3.02	0.55	1.47	Oct.	7.30	1.93	5.37
Nov.	2.07	0.71	1.36	Nov.	2.36	1.36	1.00
Dec.	4.76	3.18	1.58	Dec.	1.51	1.28	0.23
Year.	*44.27*	*23.21*	*21.06*	*Year.*	*40.93*	*23.03*	*17.90*

HYDROLOGIC DESCRIPTION.

Stream — North Branch Pawtuxet River. *Location* — Fiskeville Dam, R. I.
Record from — 1916 to 1919. *Years* — Four.
Records obtained from — Reports Providence Board of Water Supply.
Discharge obtained by — Dam used as weir. *Gage readings taken* — Recording gage.
Accuracy — Summer, excellent; winter, excellent.
Artificial regulation — Extensive reservoirs and lakes.
Diversions — None unaccounted for.
Drainage area, square miles — 101.8. Swamp, 2.26; water, 2.14; land, 97.4.
Drainage area per cent. — 4.3% water.
Areas obtained from — Providence, Burillville, Blackstone, and Franklin, sheets. U. S. Geological Survey.
Mean slope of basin — 268 ft. per mile by contour length method.
Drainage density — 1.40 mi. per sq. mi. by lengths on U. S. maps method.
Mean elevation — 437, by contour length method. *Orientation of axis* — S. 45° E.
Soil maps — Rhode Island (Providence sheet) 1904, U. S. Soils Bureau.
Soil — 90 per cent. Gloucester stony and sandy loam.
General depth to ledge rock — 0 to 5 ft.
Ledge rock, kinds and distribution — Granetic gneiss, with complex folding and faulting.
Prevailing dip — 20° to 60°. *Direction* — Varying.
Woods, per cent. — 75. *Kind* — Sparse, mixed.
Crops, per cent. — 10. *Kind* — Mixed, potatoes, truck, etc.
Grass, per cent. — 15. *Kind* — Meadow and wild pasture. *Other culture* — 00 per cent.
No. Rainfall stations — 4 (*b*).

YIELD OF NORTH BRANCH PAWTUXET RIVER AT — ABOVE FISKEVILLE DAM.
Drainage Area, 101.8 Sq. Mi.

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile. M.G.D.	Per Sq. Mile. C.F.S.	Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
1916.								
Jan.	4 519.8	225.2	1.432	2.212	1.88	1.33	2.50	—0.62
Feb.	6 554.0	350.0	2.220	3.434	5.88	.63	3.70	2.18
Mar.	7 064.9	352.7	2.239	3.465	2.46	1.62	3.99	—1.53
Apr.	8 229.0	423.6	2.691	4.161	3.60	1.29	4.64	—1.04
May	6 525.5	326.0	2.067	3.202	4.83	.76	3.69	1.14
June	6 057.0	311.8	1.983	3.063	5.71	.60	3.42	2.29
July	4 854.6	242.5	1.538	2.382	7.38	.37	2.74	4.64
Aug.	1 934.4	96.7	.613	0.948	1.33	.82	1.09	0.24
Sept.	738.0	38.1	.242	0.374	1.24	.34	.42	0.82
Oct.	905.2	45.2	.287	0.444	2.61	.20	.51	2.10
Nov.	1 032.0	53.2	.338	0.523	2.34	.25	.58	1.76
Dec.	1 711.2	55.2	.542	0.838	3.30	.30	.97	2.33
Year	*50 125.6*	*2 520.2*	*1.349*	*2.087*	*42.56*	*.67*	*28.25*	*15.31*
1917.								
Jan.	3 382.1	168.5	1.071	1.655	3.96	.48	1.91	2.05
Feb.	2 310.0	127.6	.810	1.253	2.18	.60	1.30	0.88
Mar.	7 588.8	379.5	2.405	3.728	4.91	.87	4.29	0.62
Apr.	5 391.0	277.2	1.765	2.723	2.70	1.13	3.05	—0.35
May	4 929.0	245.6	1.562	2.413	4.15	.67	2.79	1.36
June	3 858.0	198.4	1.263	1.949	4.54	.48	2.18	2.36
July	1 404.3	70.0	.445	0.688	1.51	.52	.79	0.72
Aug.	1 249.3	62.4	.396	0.613	6.13	.12	.71	5.42
Sept.	1 113.0	57.3	.364	0.563	2.66	.24	.63	2.03
Oct.	3 162.0	157.5	1.002	1.547	6.71	.27	1.79	4.92
Nov.	2 814.0	145.1	.921	1.425	.48	3.33	1.59	—1.11
Dec.	2 449.0	122.2	.776	1.200	3.23	.43	1.38	1.85
Year	*39 650.5*	*2 011.3*	*1.065*	*1.646*	*43.16*	*.52*	*22.41*	*20.75*

(*b*) Weighted mean Hopkins Mills, Rocky Hill, South Scituate, and Fiskeville. Records are total yield corrected for gain or loss of storage, but not reduced to basis of net land area.

YIELD OF NORTH BRANCH PAWTUXET RIVER. — *Continued.*

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile.		Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
			M.G.D.	C.F.S.				
1918.								
Jan.	3 236.4	162.2	1.026	1.593	3.56	.52	1.83	1.73
Feb.	7 145.6	395.3	2.507	3.883	3.73	1.09	4.04	−0.31
Mar.	5 601.7	278.7	1.775	2.738	2.15	1.47	3.17	−1.02
Apr.	6 012.0	310.2	1.969	3.047	4.56	.75	3.40	1.16
May	3 961.8	197.6	1.255	1.941	3.12	.72	2.24	0.88
June	2 187.0	112.7	0.716	1.107	4.49	.28	1.24	3.25
July	827.7	41.2	0.262	0.405	5.13	.09	0.47	4.66
Aug.	1 447.7	72.3	0.459	0.710	4.14	.20	0.82	3.32
Sept.	3 198.0	164.9	1.047	1.620	8.79	.21	1.81	6.98
Oct.	1 810.4	90.4	0.574	0.888	1.07	.96	1.02	0.05
Nov.	2 379.0	122.7	0.779	1.205	2.60	.52	1.34	1.26
Dec.	4 197.4	209.5	1.330	2.058	3.75	.63	2.37	1.38
Year	*42 004.7*	*2 157.7*	*1.131*	*1.766*	*47.09*	*.50*	*23.75*	*23.34*
1919.								
Jan.	6 742.5	336.6	2.137	3.306	4.89	.78	3.81	1.08
Feb.	4 012.4	221.7	1.408	2.178	3.42	.67	2.27	1.15
Mar.	8 862.9	442.1	2.808	4.343	6.05	.83	5.01	1.04
Apr.	7 833.0	403.9	2.565	3.968	4.31	1.03	4.43	−0.12
May	6 823.1	340.5	2.162	3.345	5.99	.65	3.86	2.13
June	2 241.0	115.5	0.734	1.135	3.65	.35	1.27	2.38
July	2 390.1	119.2	0.757	1.171	5.47	.25	1.35	4.12
Aug.	1 612.0	80.5	0.511	0.791	6.65	.14	0.91	5.74
Sept.	5 898.0	304.1	1.931	2.987	6.07	.55	3.33	2.74
Oct.	2 575.5	127.6	0.810	1.253	2.29	.64	1.45	0.84
Nov.	3 978.0	205.2	1.303	2.016	5.05	.45	2.25	2.80
Dec.	4 798.8	239.5	1.521	2.353	2.58	1.05	2.71	−0.13
Year	*57 767.3*	*2 936.4*	*1.553*	*2.404*	*56.42*	*.58*	*32.65*	*23.77*

HYDROLOGIC DESCRIPTION.

Stream — Abbott Run. *Location* — Pawtucket, R. I.
Record from — 1913 to 1919. *Years* — Six.
Records obtained from — Geo. A. Carpenter, Water Works, Pawtucket.
Discharge obtained by — Weir. *Gage readings taken* — Daily.
Accuracy — Summer, excellent; winter, excellent. *Artificial regulation* — Slight.
Diversions — None unaccounted for.
Drainage area, square miles — 26.94; swamp, 0.0; water, 0.73; land, 26.21.
Areas obtained from — Providence and Franklin.
Topographic sheets — U. S. Geological Survey.
Mean slope of basin — 334 ft. per mile by contour length method.
Drainage density — 1.8 mi. per sq. mi., by measuring on topographic maps.
Mean elevation — 258, by contour method. *Orientation of axis* — S. 10° E.
Soil maps — Rhode Island (Providence area) 1904, U. S. Soils Bureau.
General depth to ledge rock —
Ledge rock, kinds and distribution — Carboniferous, complex; mostly red sandstone and shale.
Prevailing dip — Steep. *Direction* — Varying.
Woods, per cent. — 33. *Kind* — Mixed.
Crops, per cent. — 33. *Kind* — Various.
Grass, per cent. — 33. *Kind* — Meadow and pasture.

One Rainfall station only, at Diamond Hill.

Records given are based on total actual yield corrected for gain or loss of storage, not reduced to basis of net land area. For earlier records see JOURNAL N. E. W. W. Assn., December, 1914, pp. 506–570.

YIELD OF ABBOTT RUN WATERSHED.

Drainage Area, 26.94 Sq. Mi.

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile. M.G.D.	Per Sq. Mile. C.F.S.	Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
1913.								
Jan.	1 557.837	77.6	1.865	2.886	3.33	1.00	3.33	0.00
Feb.	675.682	37.1	.896	1.386	3.03	.48	1.44	1.59
Mar.	1 717.739	85.5	2.057	3.182	6.39	.56	3.54	2.85
Apr.	1 944.708	100.1	2.406	3.723	5.06	.82	4.15	0.91
May	712.267	35.5	.853	1.320	2.30	.66	1.52	0.78
June	240.691	12.4	.298	0.461	1.15	.45	0.51	0.64
July	93.571	4.6	.112	0.173	2.48	.08	0.20	2.28
Aug.	64.818	3.2	.078	0.120	3.64	.04	0.14	3.50
Sept.	102.018	5.2	.126	0.195	3.77	.06	0.22	3.55
Oct.	397.726	19.8	.476	0.737	6.85	.12	0.85	6.00
Nov.	428.855	22.1	.531	0.821	2.66	.34	0.91	1.75
Dec.	877.363	43.6	1.051	1.625	3.88	.48	1.86	2.02
Year	*8 813.275*	*446.7*	*.896*	*1.387*	*44.54*	*.42*	*18.67*	*25.87*
1914.								
Jan.	897.198	44.7	1.074	1.662	4.22	.46	1.92	2.30
Feb.	951.255	52.5	1.261	1.951	3.37	.60	2.03	1.34
Mar.	2 440.126	121.6	2.922	4.521	5.00	1.04	5.21	−0.21
Apr.	1 864.832	96.0	2.307	3.570	5.13	.78	3.98	1.15
May	1 344.884	67.0	1.610	2.492	2.76	1.04	2.87	−0.11
June	248.977	12.8	0.308	0.477	0.97	.55	0.53	0.44
July	139.299	6.9	0.167	0.258	2.82	.11	0.30	2.52
Aug.	59.065	2.9	0.071	0.109	2.67	.05	0.12	2.55
Sept.	13.378	0.7	0.017	0.026	0.41	.08	0.03	0.38
Oct.	77.479	3.9	0.093	0.144	2.80	.06	0.17	2.63
Nov.	124.258	6.4	0.154	0.238	3.91	.07	0.27	3.64
Dec.	204.678	10.2	0.245	0.379	4.19	.11	0.44	3.75
Year	*8 365.369*	*425.6*	*0.851*	*1.316*	*38.25*	*.47*	*17.87*	*20.38*
1915.								
Jan.	1 828.165	91.2	2.189	3.387	7.60	.52	3.91	3.69
Feb.	1 752.553	96.8	2.323	3.595	4.44	.84	3.74	0.70
Mar.	703.843	36.3	0.875	1.354	0.07	22.29	1.56	−1.49
Apr.	594.971	30.7	0.736	1.139	2.32	.55	1.27	1.05
May	345.239	17.2	0.413	0.640	1.72	.44	0.74	0.98
June	206.404	10.6	0.255	0.395	3.22	.14	0.44	2.78
July	1 277.834	63.8	1.530	2.367	8.81	.31	2.73	6.08
Aug.	605.459	30.1	0.725	1.122	5.05	.26	1.29	3.76
Sept.	197.077	10.1	0.244	0.377	0.52	.81	0.42	0.10
Oct.	181.594	9.0	0.217	0.336	2.87	.14	0.39	2.48
Nov.	216.019	11.1	0.267	0.414	2.51	.19	0.46	2.05
Dec.	667.920	33.4	0.800	1.237	5.39	.27	1.43	3.96
Year	*8 604.078*	*440.3*	*0.875*	*1.354*	*44.52*	*.41*	*18.38*	*26.14*
1916.								
Jan.	874.136	43.6	1.047	1.619	2.19	.85	1.87	0.32
Feb.	1 185.469	63.2	1.517	2.348	6.03	.42	2.53	3.50
Mar.	1 547.217	77.2	1.853	2.866	3.39	.98	3.31	0.08
Apr.	2 010.951	103.6	2.488	3.850	4.17	1.03	4.29	−0.12
May	1 516.442	75.6	1.816	2.809	4.49	.72	3.24	1.25
June	1 321.940	68.1	1.636	2.531	5.98	.47	2.82	3.16
July	1 171.012	58.4	1.402	2.170	8.25	.30	2.50	5.75
Aug.	453.731	22.6	0.543	0.840	1.84	.53	0.97	0.87
Sept.	140.126	7.2	0.173	0.268	1.33	.20	0.30	1.03
Oct.	214.187	10.7	0.256	0.397	2.47	.19	0.46	2.01
Nov.	150.203	7.7	0.186	0.288	2.66	.12	0.32	2.34
Dec.	266.733	13.3	0.319	0.494	3.35	.17	0.57	2.78
Year	*10 852.147*	*551.2*	*1.104*	*1.703*	*46.15*	*.50*	*23.18*	*22.97*

YIELD OF ABBOTT RUN WATERSHED. — *Continued.*

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile.		Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
			M.G.D.	C.F.S.				
1917.								
Jan.....	615.067	30.7	0.736	1.140	3.37	.39	1.31	2.06
Feb.....	522.247	28.8	0.692	1.071	2.87	.39	1.12	1.75
Mar....	1 757.865	87.7	2.105	3.257	5.27	.71	3.76	1.51
Apr.....	1 505.640	77.5	1.863	2.883	3.09	1.04	3.22	−0.13
May...	1 290.572	64.3	1.545	2.391	4.66	.59	2.76	1.90
June...	1 110.212	57.3	1.374	2.125	4.91	.48	2.37	2.54
July....	319.156	15.9	0.382	0.591	0.95	.72	0.68	0.27
Aug....	403.744	20.1	0.484	0.748	8.15	.11	0.86	7.29
Sept....	198.990	10.2	0.246	0.381	2.46	.17	0.42	2.04
Oct.....	562.375	28.0	0.673	1.042	6.77	.18	1.20	5.57
Nov....	684.191	35.2	0.846	1.310	0.43	3.40	1.46	−1.03
Dec. ...	570.681	28.5	0.683	1.057	3.42	.36	1.22	2.20
Year...	*9 540.735*	*484.2*	*0.970*	*1.501*	*46.35*	*.44*	*20.38*	*25.97*
1918.								
Jan.....	800.456	39.8	0.985	1.483	3.94	.44	1.71	2.23
Feb.....	1 513.658	83.7	2.007	3.105	2.81	1.15	3.23	−0.42
Mar....	1 415.786	70.5	1.695	2.623	2.66	1.14	3.02	−0.36
Apr.....	1 345.935	69.4	1.665	2.577	4.09	.70	2.87	1.22
May...	863.851	43.0	1.034	1.600	2.49	.75	1.85	0.64
June...	316.052	16.3	0.391	0.605	3.48	.20	0.68	2.80
July....	111.516	5.6	0.134	0.207	2.63	.09	0.24	2.39
Aug....	76.641	3.8	0.092	0.142	1.93	.09	0.16	1.77
Sept....	562.147	29.1	0.696	1.076	9.20	.13	1.20	8.00
Oct.....	367.785	18.3	0.440	0.681	0.60	1.32	0.79	−0.19
Nov....	365.710	18.8	0.452	0.700	2.29	.34	0.78	1.51
Dec. ...	861.278	43.0	1.031	1.596	3.88	.48	1.84	2.04
Year...	*8 600.815*	*441.3*	*0.875*	*1.353*	*40.00*	*.46*	*18.37*	*21.63*
1919.								
Jan.....	1 492.447	74.5	1.787	2.765	4.81	.66	3.19	1.62
Feb.....	1 039.704	57.3	1.378	2.133	3.43	.65	2.22	1.21
Mar....	2 131.010	106.2	2.552	3.948	5.53	.82	4.55	0.98
Apr.....	1 560.224	80.4	1.930	2.987	3.28	1.02	3.33	−0.05
May...	1 343.004	67.0	1.608	2.488	5.25	.55	2.87	2.38
June...	419.062	21.6	0.519	0.802	1.95	.47	0.90	1.05
July....	399.119	19.9	0.478	0.739	5.99	.14	0.85	5.14
Aug....	248.055	12.4	0.297	0.460	4.64	.12	0.53	4.11
Sept....	1 028.761	53.0	1.273	1.969	5.36	.41	2.20	3.16
Oct.....	519.810	25.9	0.622	0.963	2.32	.48	1.11	1.21
Nov....	994.418	51.1	1.231	1.904	3.73	.57	2.12	1.61
Dec. ...	1 122.803	54.0	1.344	2.008	2.24	1.08	2.40	−0.16
Year...	*12 298.417*	*623.3*	*1.251*	*1.935*	*48.53*	*.54*	*26.27*	*22.26*

HYDROLOGIC DESCRIPTION.

Stream — Stony Brook.
Location — Cambridge, Mass.
Record from — 1909 to 1919. *Years* — Twelve.
Records obtained from — L. M. Hastings, city engineer.
Discharge obtained by — Reservoir and pumpage records.
Gage readings taken — Daily.
Accuracy — Summer, good; winter, good.
Diversions — None unaccounted for.
Drainage area, square miles — 23.57. Swamp, 2.00; water, 1.00; land, 20.57.
Areas obtained from — Boston and Framingham topographic sheets, U. S. Geological Survey.
Mean slope of basin — Not determined.
Drainage density — Not determined.
Mean elevation — Not determined.
Orientation of axis — S. 50° E.
Soil maps — Not available
Soil — Sandy loam.
General depth to ledge rock — Unknown.
Ledge rock, kinds and distribution — Complex, mainly igneous gneisses and schists.
Prevailing dip — Unknown. *Direction* — Unknown
Woods, per cent. — 50. *Kind* — Sparse, mixed.
Crops, per cent. — 20–30. *Grass, per cent.* — 20–30.

For earlier records see JOURNAL N. E. W. W. Assn., December, 1914, pp. 486-487.

Figures here given are actual yield corrected for storage but not reduced to basis of net land area.

YIELD OF STONY BROOK WATERSHED.
Drainage Area, 23.57 Sq. Mi.

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile. M.G.D.	Per Sq. Mile. C.F.S.	Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
1912.								
Jan.	572.0	28.6	0.783	1.211	2.65	.39	1.04	1.61
Feb.	884.3	47.2	1.294	1.996	2.43	.86	2.08	0.35
Mar.	1 825.9	91.3	2.499	3.867	5.93	.75	4.46	1.47
Apr.	1 440.3	74.5	2.037	3.156	4.01	.76	3.03	0.98
May	901.9	44.8	1.234	1.903	5.14	.43	2.20	2.94
June	151.2	7.8	0.214	0.331	0.24	1.56	.37	−0.13
July	120.9	6.0	0.165	0.255	5.06	.06	.30	4.76
Aug.	66.2	3.3	0.091	0.139	2.40	.07	.16	2.24
Sept.	18.4	0.9	0.026	0.040	1.94	.03	.05	1.89
Oct.	107.3	5.3	0.147	0.227	2.76	.10	.26	2.50
Nov.	219.6	11.4	0.311	0.481	3.01	.18	.54	2.47
Dec.	424.7	21.2	0.581	0.899	4.88	.21	1.04	3.84
Year	*6 732.7*	*342.3*	*0.782*	*1.209*	*40.45*	*.38*	*15.53*	*24.92*
1913.								
Jan.	820.0	40.8	1.122	1.733	2.82	.71	2.00	0.82
Feb.	493.4	27.3	0.748	1.157	3.17	.38	1.20	1.97
Mar.	1 322.5	66.0	1.809	2.800	5.30	.61	3.23	2.07
Apr.	1 447.0	74.8	2.046	3.171	4.28	.83	3.53	0.75
May	658.1	33.9	0.933	1.443	3.99	.42	1.67	2.32
June	148.0	7.6	0.209	0.323	1.17	.31	0.36	0.81
July	36.0	2.5	0.068	0.105	3.15	.03	0.10	3.05
Aug.	168.0	8.4	0.229	0.354	3.98	.11	0.41	3.57
Sept.	106.0	5.5	0.149	0.231	3.34	.08	0.26	3.08
Oct.	456.0	22.8	0.624	0.965	5.90	.06	0.36	5.54
Nov.	355.0	18.3	0.502	0.777	2.16	.40	0.87	1.29
Dec.	604.5	30.2	0.827	1.279	2.85	.52	1.48	1.37
Year	*6 614.5*	*338.1*	*0.772*	*1.195*	*42.11*	*.37*	*15.47*	*26.64*

YIELD OF STONY BROOK WATERSHED. — *Continued.*

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile.		Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
			M.G.D.	C.F.S.				
1914.								
Jan.	424.7	21.2	0.581	0.899	3.23	.32	1.04	2.19
Feb.	591.9	32.7	0.896	1.386	3.07	.47	1.45	1.62
Mar.	2 190.6	109.2	2.988	4.626	4.82	1.11	5.35	−0.53
Apr.	1 841.1	94.9	2.604	4.022	5.25	.86	4.50	0.75
May	1 314.4	65.8	1.799	2.785	2.60	1.24	3.21	−0.61
June	93.0	4.8	0.131	0.203	1.94	.12	0.23	1.71
July	97.0	4.9	0.133	0.206	2.46	.10	0.24	2.22
Aug.	79.0	3.9	0.108	0.167	3.92	.05	0.20	3.72
Sept.	−15.0	−0.7	−0.021	−0.032	0.24	−.17	−0.04	0.28
Oct.	15.0	0.7	0.021	0.032	1.69	.03	0.04	1.65
Nov.	77.0	4.0	0.109	0.169	2.57	.08	0.19	2.38
Dec.	171.0	8.5	0.234	0.362	3.39	.13	0.42	2.97
Year	*6 879.7*	*349.9*	*0.815*	*1.235*	*35.18*	*.48*	*16.83*	*18.35*
1915.								
Jan.	892.8	44.3	1.222	1.889	5.89	.37	2.18	3.71
Feb.	1 128.4	62.3	1.709	2.645	3.65	.76	2.76	0.89
Mar.	408.6	20.4	0.559	0.865	....	....	1.00	−1.00
Apr.	425.1	21.9	0.601	0.930	2.31	.45	1.04	1.27
May	256.8	12.6	0.351	0.543	2.38	.27	0.63	1.75
June	216.0	7.0	0.192	0.297	1.66	.20	0.33	1.33
July	742.5	37.2	1.016	1.578	9.95	.18	1.81	8.14
Aug.	820.4	41.7	1.123	1.766	6.22	.32	2.00	4.22
Sept.	96.0	5.0	0.136	0.210	0.94	.25	0.23	0.71
Oct.	171.0	8.5	0.234	0.362	2.98	.14	0.42	2.56
Nov.	552.8	28.6	0.782	1.210	2.68	.25	0.66	2.02
Dec.	576.0	28.8	0.788	1.219	5.13	.28	1.41	3.72
Year	*6 286.4*	*318.5*	*0.726*	*1.126*	*43.79*	*.33*	*14.47*	*29.32*
1916.								
Jan.	179.8	9.0	0.246	0.381	1.35	.33	0.44	0.91
Feb.	919.9	48.9	1.336	2.073	5.35	.42	2.23	3.12
Mar.	1 383.4	68.9	1.893	2.924	4.13	.82	3.37	0.76
Apr.	1 955.2	100.8	2.765	4.270	4.39	1.09	4.77	−0.38
May	1 147.1	57.3	1.570	2.429	3.19	.88	2.80	0.39
June	1 022.1	52.6	1.445	2.228	5.87	.43	2.50	3.37
July	368.9	18.4	0.505	0.781	3.53	.26	0.90	2.63
Aug.	90.5	4.5	0.124	0.192	2.14	.10	0.22	1.92
Sept.	1 300.0	67.3	1.838	2.847	1.45	.23	0.32	1.13
Oct.	36.0	1.8	0.049	0.076	1.19	.08	0.09	1.10
Nov.	79.0	4.1	0.112	0.173	1.70	.12	0.19	1.51
Dec.	195.0	9.7	0.267	0.413	3.79	.13	0.48	3.31
Year	*8 676.9*	*443.3*	*1.013*	*1.566*	*38.08*	*.48*	*18.31*	*19.77*
1917.								
Jan.	354.0	17.7	0.484	0.749	3.02	.29	0.86	2.16
Feb.	785.1	43.4	1.189	1.841	2.57	.75	1.91	0.66
Mar.	1 307.9	65.4	1.790	2.769	4.34	.74	3.19	1.15
Apr.	963.3	49.6	1.362	2.104	2.67	.88	2.35	0.32
May	1 068.3	53.3	1.462	2.259	4.82	.54	2.61	2.21
June	732.0	38.0	1.035	1.609	4.11	.43	1.78	2.33
July	106.3	5.3	0.146	0.226	1.02	.26	0.26	0.76
Aug.	159.0	8.0	0.218	0.337	4.11	.10	0.39	3.72
Sept.	36.0	1.9	0.051	0.079	1.97	.05	0.09	1.88
Oct.	326.0	16.3	0.446	0.690	5.61	.14	0.80	4.81
Nov.	188.0	9.8	0.270	0.416	0.82	.57	0.46	0.36
Dec.	195.0	9.7	0.267	0.413	2.84	.17	0.48	2.36
Year	*6 220.9*	*318.4*	*0.727*	*1.124*	*37.90*	*.40*	*15.18*	*22.72*

YIELD OF STONY BROOK WATERSHED. — *Continued.*

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile. M.G.D.	Per Sq. Mile. C.F.S.	Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
1918.								
Jan.	168.0	8.4	0.229	0.354	3.12	.13	0.41	2.71
Feb.	1 061.4	61.3	1.683	2.599	2.34	1.16	2.71	−0.37
Mar.	1 248.7	62.5	1.709	2.645	3.35	.91	3.05	0.30
Apr.	915.6	47.4	1.295	2.011	2.94	.76	2.24	0.70
May	431.2	21.5	0.590	0.913	2.34	.45	1.05	1.29
June	171.0	8.8	0.242	0.374	3.07	.14	0.42	2.65
July	87.1	4.3	0.119	0.184	3.54	.06	0.21	3.33
Aug.	−28.0	−1.4	−0.038	−0.059	1.78	.04	0.07	1.71
Sept.	462.0	23.8	0.653	1.010	8.82	.13	1.11	7.71
Oct.	220.1	11.0	0.301	0.466	0.93	.59	0.54	0.39
Nov.	285.0	14.7	0.403	0.623	2.40	.29	0.70	1.70
Dec.	602.3	19.4	0.824	1.275	3.36	.44	1.47	1.89
Year	*5 624.4*	*281.7*	*0.668*	*1.033*	*37.99*	*.37*	*13.98*	*24.01*
1919.								
Jan.	873.1	43.4	1.186	1.841	4.00	.53	2.13	1.87
Feb.	849.0	47.2	1.286	1.996	3.21	.65	2.07	1.14
Mar.	1 478.1	73.6	3.023	3.125	4.54	.80	3.61	0.93
Apr.	967.8	50.0	1.368	2.119	2.72	.87	2.35	0.37
May	1 054.0	52.6	1.442	2.228	5.81	.44	2.57	3.24
June	24.6	1.3	0.035	0.054	1.39	.43	0.60	0.79
July	264.0	13.2	0.361	0.558	5.75	.11	0.64	5.11
Aug.	222.0	11.1	0.304	0.470	5.49	.10	0.54	4.95
Sept.	632.9	32.6	0.895	1.384	7.42	.21	1.57	5.85
Oct.	212.3	10.6	0.291	0.450	2.10	.25	0.52	1.58
Nov.	875.5	45.3	1.238	1.918	5.38	.40	2.14	3.24
Dec.	896.8	44.8	1.227	1.903	1.73	1.27	2.19	−0.46
Year	*8 359.1*	*425.7*	*0.971*	*1.504*	*49.54*	*.42*	*20.93*	*28.61*

HYDROLOGIC DESCRIPTION.

Springfield Water Works. *Stream* — Westfield Little River.

Location — Near Westfield, Mass.

Record from — 1912 to 1919. *Years* — Eight

Records obtained from — E. E. Lochridge, chief engineer.

Discharge obtained by — Weir. *Gage readings taken* — Daily.

Accuracy — Summer, excellent; winter, excellent.

Artificial regulation — None. *Diversions* — None.

Drainage area, square miles — 48.50. Swamp; water, 0.69; land, 47.81.

Areas obtained from — Granville and Standisfield. Topographic sheets — U. S. Geological Survey maps.

Mean slope of basin — 535 ft. per mile by contour method.

Drainage density — Not determined.

Mean elevation — Not determined.

Orientation of axis — S. 45° E.

Soil maps — None available.

General depth to ledge rock — 0 to 5 ft.

Ledge rock, kinds and distribution — Granetic.

Prevailing dip — Not determined. *Direction* — Not determined.

Woods, per cent. — 75. *Kind* — Mixed.

Crops, per cent. — 5. *Grass, per cent.* — 20.

Figures given show actual yield corrected for gain or loss of storage, but not reduced to basis of net land area. For earlier records see Water Supply Papers, U. S. Geological Survey, for North Atlantic Slope Drainage basins. Also JOURNAL N. E. W. W. Assn., December, 1914, pp. 500–502.

YIELD OF WESTFIELD LITTLE RIVER, NEAR WESTFIELD.

Drainage Area, 48.5 Sq. Mi.

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile.		Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
			M.G.D.	C.F.S.				
1912.								
Jan.....	1 511	76.1	1.01	1.57	2.56	.70	1.79	0.77
Feb.....	2 553	135.8	1.81	2.80	3.04	1.00	3.03	0.01
Mar....	7 049	352.1	4.69	7.26	5.88	1.42	8.36	−2.48
Apr.....	4 837	249.8	3.32	5.15	5.81	.99	5.74	0.07
May...	3 033	151.8	2.02	3.13	4.91	.73	3.60	1.31
June...	835	42.7	0.57	0.88	0.54	1.84	0.99	−0.45
July....	126	5.8	0.08	0.12	2.55	.06	0.15	2.40
Aug....	231	11.1	0.15	0.23	3.83	.07	0.27	3.56
Sept....	334	17.5	0.23	0.36	3.79	.11	0.40	3.39
Oct.....	744	36.9	0.49	0.76	5.57	.16	0.88	4.69
Nov....	1 837	94.6	1.26	1.95	4.60	.47	2.18	2.42
Dec....	2 297	114.5	1.52	2.36	4.81	.57	2.72	2.09
Year...	*25 387*	*1 288.7*	*1.43*	*2.22*	*47.89*	*.63*	*30.11*	*17.78*
1913.								
Jan.....	3 342	167.8	2.23	3.46	4.21	.94	3.96	0.25
Feb.....	897	49.5	0.66	1.02	2.33	.46	1.06	1.27
Mar....	4 171	208.1	2.77	4.29	6.47	.77	4.95	1.52
Apr.....	2 553	131.4	1.75	2.71	3.90	.78	3.03	0.87
May...	1 794	90.2	1.20	1.86	4.97	.43	2.13	2.84
June...	404	20.8	0.28	0.43	1.00	.48	0.48	0.52
July....	48	2.4	0.03	0.05	1.51	.04	0.06	1.45
Aug....	71	3.9	0.05	0.08	2.56	.03	0.08	2.48
Sept....	158	8.2	0.11	0.17	3.34	.06	0.19	3.15
Oct.....	2 001	99.9	1.33	2.06	8.45	.28	2.37	6.08
Nov....	2 223	114.5	1.52	2.36	4.80	.55	2.64	2.16
Dec....	1 574	79.1	1.05	1.63	2.94	.64	1.87	1.07
Year...	*19 236*	*975.8*	*1.08*	*1.67*	*46.48*	*.49*	*22.82*	*23.66*
1914.								
Jan.....	1 142	57.2	0.76	1.18	2.32	.59	1.36	0.96
Feb.....	1 190	66.0	0.88	1.36	4.14	.34	1.41	2.73
Mar....	4 644	232.3	3.09	4.79	6.60	.84	5.51	1.09
Apr.....	6 056	312.8	4.16	6.45	6.13	1.17	7.19	−1.06
May...	2 200	109.6	1.46	2.26	2.44	1.07	2.61	−0.17
June...	253	13.6	0.18	0.28	2.33	.13	0.30	2.03
July....	265	13.6	0.18	0.28	3.61	.09	0.31	3.30
Aug....	108	5.3	0.07	0.11	2.27	.06	0.13	2.14
Sept....	46	2.4	0.03	0.05	0.19	.26	0.05	0.14
Oct.....	104	5.3	0.07	0.11	2.31	.06	0.12	2.19
Nov....	808	41.2	0.55	0.85	3.75	.26	0.96	2.79
Dec....	347	17.5	0.23	0.36	4.60	.09	0.41	4.19
Year...	*17 163*	*876.8*	*0.97*	*1.50*	*40.69*	*.49*	*20.36*	*20.33*
1915.								
Jan.....	3 552	177.5	2.36	3.66	7.43	.57	4.21	3.22
Feb.....	4 530	250.7	3.34	5.17	6.24	.86	5.37	0.87
Mar....	1 027	50.9	0.68	1.05	0.35	3.49	1.22	−0.87
Apr.....	2 706	139.7	1.86	2.88	3.94	.81	3.21	0.73
May...	1 626	81.0	1.08	1.67	2.36	.82	1.93	0.43
June...	678	34.9	0.47	0.72	4.70	.17	0.80	3.90
July....	2 232	111.1	1.48	2.29	7.18	.37	2.65	4.53
Aug....	2 090	104.3	1.39	2.15	8.39	.30	2.48	5.91
Sept....	395	19.8	0.27	0.41	2.55	.19	0.47	2.08
Oct.....	569	28.6	0.38	0.59	2.62	.26	0.67	1.95
Nov....	831	42.7	0.57	0.88	3.60	.28	0.99	2.61
Dec....	2 791	139.7	1.86	2.88	8.58	.39	3.31	5.27
Year...	*23 027*	*1 180.9*	*1.30*	*2.02*	*57.94*	*.47*	*27.31*	*30.63*

YIELD OF WESTFIELD LITTLE RIVER. — *Continued.*

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile.		Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
			M.G.D.	C.F.S.				
1916.								
Jan.	2 662	132.9	1.77	2.74	2.40	1.32	3.16	−0.76
Feb.	2 345	124.6	1.66	2.57	6.79	.41	2.78	4.01
Mar.	1 779	88.8	1.18	1.83	5.45	.39	2.11	3.34
Apr.	6 936	358.4	4.77	7.39	4.19	1.96	8.22	−4.03
May	1 861	93.1	1.24	1.92	3.64	.61	2.21	1.43
June	1 989	102.3	1.36	2.11	5.85	.40	2.36	3.49
July	1 474	73.7	0.98	1.52	6.26	.28	1.75	4.51
Aug.	398	20.4	0.27	0.42	2.65	.18	0.47	2.18
Sept.	710	36.9	0.49	0.76	6.70	.13	0.84	5.86
Oct.	532	27.2	0.36	0.56	1.56	.41	0.63	0.93
Nov.	1 004	51.9	0.69	1.07	4.44	.27	1.19	3.25
Dec.	1 338	66.9	0.89	1.38	3.70	.43	1.59	2.11
Year	*23 028*	*1 177.1*	*1.30*	*2.02*	*53.63*	*.54*	*27.31*	*26.32*
1917.								
Jan.	1 678	84.4	1.12	1.74	3.18	.63	1.99	1.19
Feb.	896	49.5	0.66	1.02	4.12	.26	1.06	3.06
Mar.	2 848	142.1	1.89	2.93	4.75	.71	3.38	1.37
Apr.	5 010	258.5	3.44	5.33	3.20	1.86	5.95	−2.75
May	2 937	146.5	1.95	3.02	4.20	.83	3.48	0.72
June	1 925	99.4	1.32	2.05	5.15	.44	2.28	2.87
July	424	20.9	0.28	0.43	2.35	.21	0.50	1.85
Aug.	259	12.6	0.17	0.26	3.73	.09	0.31	3.42
Sept.	210	10.7	0.14	0.22	1.00	.25	0.25	0.75
Oct.	1 116	55.8	0.74	1.15	8.65	.15	1.32	7.33
Nov.	690	35.4	0.47	0.73	0.90	.92	0.82	0.08
Dec.	484	24.2	0.32	0.50	4.90	.12	0.58	4.32
Year	*18 477*	*940.0*	*1.04*	*1.61*	*46.13*	*.48*	*21.92*	*24.21*
1918.								
Jan.	633	33.0	0.44	0.68	3.40	.23	0.79	2.61
Feb.	2 002	110.6	1.47	2.28	3.82	.62	2.37	1.45
Mar.	5 412	270.6	3.60	5.58	2.83	2.27	6.42	−3.59
Apr.	3 021	155.7	2.07	3.21	3.51	1.02	3.58	−0.07
May	1 158	57.7	0.77	1.19	2.02	.68	1.37	0.65
June	597	31.0	0.41	0.64	2.35	.31	0.71	1.64
July	176	9.2	0.12	0.19	2.65	.08	0.21	2.44
Aug.	227	11.2	0.15	0.23	4.06	.07	0.27	3.79
Sept.	618	31.5	0.42	0.65	6.83	.11	0.73	6.10
Oct.	368	17.9	0.24	0.37	1.47	.30	0.44	1.03
Nov.	796	41.2	0.55	0.85	2.92	.32	0.94	1.98
Dec.	1 826	91.2	1.21	1.88	3.83	.57	2.17	1.66
Year	*16 864*	*860.8*	*0.95*	*1.48*	*39.69*	*.50*	*20.00*	*19.69*
1919.								
Jan.	1 403	70.3	0.93	1.45	2.52	.66	1.67	0.85
Feb.	593	33.0	0.44	0.68	4.06	.17	0.70	3.36
Mar.	4 656	233.3	3.10	4.81	5.61	.99	5.53	0.08
Apr.	4 109	212.4	2.82	4.38	3.67	1.33	4.87	−1.20
May	4 453	222.6	2.96	4.59	8.76	.60	5.28	3.48
June	425	21.8	0.29	0.45	1.04	.49	0.50	0.54
July	383	19.4	0.25	0.40	5.00	.09	0.45	4.55
Aug.	306	15.5	0.20	0.32	3.80	.09	0.36	3.44
Sept.	584	30.1	0.40	0.62	6.11	.11	0.69	5.42
Oct.	460	23.3	0.31	0.48	2.52	.22	0.55	1.97
Nov.	2 273	117.3	1.56	2.42	7.06	.38	2.70	4.36
Dec.	1 854	92.6	1.23	1.91	2.70	.82	2.20	0.50
Year	*21 499*	*1 091.6*	*1.21*	*1.88*	*52.85*	*.48*	*25.50*	*27.35*

Hydrologic Description.

Stream — Manhan River. *Location* — Southampton, Mass.
Records from — 1897 to 1919. *Years* — Twenty-three.
Records obtained from — P. J. Lucey, engineer, Holyoke Water Department.
Discharge obtained by — Weir. *Gage readings taken* — Daily.
Accuracy — Summer, excellent; winter, excellent.
Artificial regulation — None. *Diversions* — None unaccounted for.
Drainage area, square miles — 13. Swamp, 0.33; water, little; land, 13.
Areas obtained from — Springfield, Granville, and Chesterfield. Topographic Sheets, U. S. Geological Survey.
Mean slope of basin — 552 ft. per mile by contour method.
Drainage density — Not determined.
Mean elevation — 950 ft. by contour method.
Orientation of axis — S. 20° E.
Soil maps — Conn. Valley sheet (1903), U. S. Soils Bureau.
Soil — Sandy loam.
General depth to ledge rock — Unknown.
Ledge rock, kinds and distribution — Granetic.
Prevailing dip — Unknown. *Direction* — Unknown.
Woods, per cent. — 65. *Kind* — Mixed, sparse.
Crops, per cent. — 10. *Grass, per cent.* — 25.
Number rainfall stations — 1.

Records given show actual yield corrected for gain and loss of storage but not reduced to a basis of net land area. See also Journal N. E. W. W. Assn., December, 1914, pp. 486–488, and December, 1920, pp. 323–356.

Yield of Southwest Branch of Manhan River at Southampton, Mass.
Drainage Area, 13 Sq. Mi.

Month.	Per Sq. Mile.		Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
	M.G.D.	C.F.S.				
1897.						
Jan.	0.645	0.998	4.29	.268	1.150	3.140
Feb.	1.071	1.655	2.89	.596	1.723	1.167
Mar.	2.439	3.775	3.27	1.331	4.352	−1.082
Apr.	2.087	3.233	2.41	1.497	3.608	−1.198
May	1.168	1.810	4.05	.515	2.087	1.963
June	1.629	2.521	7.16	.393	2.814	4.346
July	4.560	7.054	13.96	.583	8.132	5.828
Aug.	1.911	2.955	6.32	.539	3.407	2.913
Sept.	0.583	0.902	1.235	.815	1.007	0.228
Oct.	0.317	0.490	1.25	.452	0.565	0.685
Nov.	1.122	1.732	6.01	.321	1.933	4.077
Dec.	2.301	3.558	6.57	.624	4.101	2.469
Year	*1.661*	*2.569*	*59.415*	*.587*	*34.879*	*24.536*
1898.						
Jan.	1.378	2.134	5.765	.427	2.461	3.304
Feb.	1.117	1.732	4.47	.404	1.804	2.666
Mar.	3.777	5.847	2.49	2.707	6.741	−4.251
Apr.	2.293	3.542	4.195	.942	3.953	0.242
May	2.443	3.774	6.16	.706	4.351	1.809
June	1.236	1.918	4.165	.513	2.139	2.026
July	0.345	0.534	3.955	.156	0.616	3.339
Aug.	0.670	1.036	7.275	.164	1.194	6.081
Sept.	0.298	0.461	3.35	.153	0.514	2.836
Oct.	1.269	1.964	7.405	.306	2.265	5.140
Nov.	1.912	2.955	5.92	.557	3.296	2.624
Dec.	1.519	2.351	3.73	.727	2.711	1.019
Year	*1.526*	*2.360*	*58.88*	*.544*	*32.045*	*26.835*

YIELD OF SOUTHWEST BRANCH OF MANHAN RIVER. — *Continued.*

Month.	Per Sq. Mile.		Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
	M.G.D.	C.F.S.				
1899.						
Jan.	1.470	2.274	3.04	.861	2.62	0.42
Feb.	0.723	1.118	3.36	.346	1.16	2.20
Mar.	1.633	2.526	6.87	.424	2.91	3.96
Apr.	4.926	7.622	1.92	4.429	8.50	−6.58
May	0.826	1.278	1.31	1.124	1.47	−0.16
June	0.248	0.383	2.43	.175	0.43	2.00
July	0.364	0.563	5.07	.128	0.65	4.42
Aug.	0.128	0.198	1.94	.117	0.23	1.71
Sept.	0.298	0.461	5.01	.102	0.51	4.50
Oct.	0.198	0.303	1.31	.268	0.35	0.96
Nov.	0.434	0.671	3.16	.237	0.75	2.41
Dec.	0.451	0.697	2.86	.281	0.80	2.06
Year	*0.975*	*1.508*	*38.28*	*.532*	*20.38*	*17.90*
1900.						
Jan.	0.472	0.733	3.59	.234	0.84	2.75
Feb.	4.150	6.421	10.28	.650	6.69	3.59
Mar.	2.801	4.344	5.54	.901	4.99	0.55
Apr.	1.985	3.071	1.88	1.817	3.42	−1.54
May	1.521	2.353	4.44	.611	2.71	1.73
June	0.374	0.578	1.78	.362	0.64	1.14
July	0.149	0.235	2.49	.106	0.16	2.33
Aug.	0.170	0.263	3.91	.077	0.30	3.61
Sept.	0.079	0.122	2.11	.064	0.13	1.98
Oct.	0.183	0.283	3.42	.095	0.32	3.10
Nov.	0.993	1.536	4.31	.397	1.71	2.60
Dec.	0.951	1.471	3.27	.518	1.70	1.57
Year	*1.152*	*1.784*	*47.02*	*.502*	*23.61*	*23.41*
1901.						
Jan.	0.304	0.470	2.11	.257	0.542	1.568
Feb.	0.197	0.305	0.78	.406	0.317	0.463
Mar.	2.214	3.419	6.29	.630	3.941	2.349
Apr.	6.517	10.086	10.98	1.025	11.252	−0.272
May	3.969	6.141	9.87	.717	7.080	2.790
June	1.016	1.577	1.96	.898	1.760	0.200
July	0.289	0.447	2.59	.199	0.515	2.075
Aug.	0.626	0.968	6.15	.181	1.116	5.034
Sept.	0.861	1.332	4.76	.312	1.486	3.274
Oct.	0.767	1.186	4.77	.287	1.369	3.401
Nov.	0.525	0.812	1.54	.588	0.906	0.634
Dec.	2.643	4.084	4.79	.983	4.709	0.081
Year	*1.667*	*2.569*	*56.59*	*.618*	*34.993*	*21.597*
1902.						
Jan.	2.342	3.620	3.32	1.257	4.173	−0.853
Feb.	1.296	2.011	4.66	4.99	2.094	2.566
Mar.	4.290	6.637	6.38	1.199	7.651	−1.271
Apr.	2.325	3.635	4.45	.911	4.055	0.395
May	0.995	1.539	2.08	.853	1.775	0.305
June	0.396	0.613	2.85	.240	0.684	2.166
July	0.558	0.863	5.75	.173	0.994	4.756
Aug.	0.502	0.776	4.63	.196	0.894	3.736
Sept.	0.761	1.177	5.34	.246	1.313	4.027
Oct.	1.652	2.552	6.99	.421	2.943	4.047
Nov.	0.914	1.414	1.62	.974	1.577	0.043
Dec.	1.815	2.800	7.46	.433	3.228	4.232
Year	*1.493*	*2.303*	*55.53*	*.565*	*31.381*	*24.149*

YIELD OF SOUTHWEST BRANCH OF MANHAN RIVER. — *Continued.*

Month.	Per Sq. Mile.		Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
	M.G.D.	C.F.S.				
1903.						
Jan.	1.472	2.274	1.88	1.394	2.622	−0.742
Feb.	2.077	3.218	5.30	0.632	3.351	1.949
Mar.	4.055	6.280	5.57	1.300	7.240	−1.670
Apr.	2.720	4.208	3.63	1.293	4.694	−1.064
May	0.549	0.849	0.89	1.099	0.978	−0.088
June	2.719	4.208	14.33	0.328	4.694	9.636
July	1.139	1.764	3.80	0.535	2.034	1.766
Aug.	1.472	2.274	7.815	0.336	2.622	5.193
Sept.	0.648	1.002	2.385	0.468	1.118	1.267
Oct.	1.358	2.103	3.915	0.619	2.425	1.490
Nov.	0.965	1.493	1.70	0.977	1.664	0.036
Dec.	1.562	2.412	6.28	0.443	2.780	3.500
Year	*1.728*	*2.674*	*57.495*	*.625*	*36.222*	*21.273*
1904.						
Jan.	0.707	1.094	3.60	0.349	1.261	2.339
Feb.	0.662	1.024	2.61	0.423	1.104	1.506
Mar.	2.650	4.099	4.43	1.067	4.726	−0.296
Apr.	4.751	7.348	6.87	1.193	8.197	−1.327
May	1.741	2.692	4.22	0.735	3.104	1.116
June	2.119	3.280	6.65	0.550	3.659	2.991
July	0.642	0.993	3.01	0.380	1.144	1.866
Aug.	0.503	0.778	5.07	0.177	0.896	4.174
Sept.	0.848	1.312	4.73	0.309	1.464	3.266
Oct.	0.936	1.448	3.56	0.468	1.668	1.892
Nov.	0.617	0.954	1.00	1.065	1.065	−0.065
Dec.	0.639	0.988	2.96	0.384	1.138	1.822
Year	*1.398*	*2.167*	*48.71*	*.604*	*29.426*	*19.284*
1905.						
Jan.	2.266	3.512	4.75	.853	4.049	0.701
Feb.	0.588	0.909	1.72	.550	0.946	0.774
Mar.	2.950	4.563	3.69	1.425	5.260	−1.570
Apr.	2.572	3.976	2.70	1.642	4.435	−1.735
May	0.633	0.979	0.99	1.139	1.128	−0.138
June	0.378	0.584	2.99	.217	0.651	2.339
July	0.471	0.729	5.96	.141	0.840	5.120
Aug.	0.232	0.359	5.54	.747	0.414	5.126
Sept.	1.806	2.800	8.89	.351	3.124	5.766
Oct.	0.667	1.032	2.94	.404	1.189	1.751
Nov.	0.621	0.961	1.86	.576	1.072	0.788
Dec.	0.969	1.499	4.16	.415	1.727	2.433
Year	*1.183*	*1.825*	*46.19*	*.538*	*24.835*	*21.355*
1906.						
Jan.	1.149	1.779	2.64	0.776	2.050	0.590
Feb.	0.731	1.131	2.43	0.485	1.178	1.252
Mar.	1.633	2.522	4.45	0.653	2.908	1.542
Apr.	3.004	4.642	5.37	0.964	5.179	0.191
May	1.387	2.150	5.45	0.455	2.479	2.971
June	0.624	0.965	3.34	0.322	1.076	2.264
July	0.518	0.801	6.51	0.142	0.923	5.587
Aug.	0.312	0.483	2.59	0.215	0.557	2.033
Sept.	0.187	0.289	2.99	0.107	0.322	2.668
Oct.	0.680	1.052	2.80	0.433	1.213	1.587
Nov.	0.738	1.142	3.01	0.423	1.274	1.736
Dec.	0.748	1.157	3.66	0.364	1.333	2.327
Year	*0.976*	*1.509*	*45.24*	*.453*	*20.492*	*24.748*

YIELD OF SOUTHWEST BRANCH OF MANHAN RIVER. — *Continued.*

Month.	Per Sq. Mile.		Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
	M.G.D.	C.F.S.				
1907.						
Jan.	1.303	2.011	2.92	0.794	2.318	0.602
Feb.	0.543	0.840	1.62	0.540	0.875	0.745
Mar.	2.327	3.604	1.96	2.120	4.155	−2.195
Apr.	1.480	2.289	2.49	1.025	2.553	−0.063
May	1.232	1.903	3.77	0.582	2.193	1.577
June	0.976	1.510	4.54	0.371	1.685	2.855
July	0.300	0.464	2.85	0.188	0.535	2.315
Aug.	0.095	0.147	1.73	0.977	0.169	1.561
Sept.	1.534	2.667	11.58	0.257	2.975	8.605
Oct.	2.247	3.481	6.70	0.599	4.013	2.687
Nov.	3.134	4.842	6.59	0.820	5.403	1.187
Dec.	1.610	2.491	4.91	0.585	2.872	2.038
Year	*1.402*	*2.180*	*51.66*	*0.579*	*29.746*	*21.914*
1908.						
Jan.	1.778	2.751	3.41	.930	3.17	0.24
Feb.	1.463	2.263	4.84	.504	2.44	2.40
Mar.	2.472	3.825	3.44	1.282	4.41	−0.97
Apr.	1.945	3.009	3.19	1.052	3.36	−0.17
May	2.844	4.400	7.19	.706	5.07	2.12
June	0.737	1.140	1.70	.748	1.27	0.43
July	0.420	0.649	4.40	.170	0.75	3.65
Aug.	0.343	0.530	4.10	.149	0.61	3.49
Sept.	0.170	0.269	1.85	.158	0.29	1.56
Oct.	0.238	0.368	2.62	.162	0.42	2.20
Nov.	0.253	0.391	1.02	.428	0.43	0.59
Dec.	0.275	0.425	2.91	.168	0.49	2.42
Year	*1.078*	*1.668*	*40.67*	*.558*	*22.71*	*17.96*
1909.						
Jan.	0.683	1.056	4.33	.281	1.02	3.31
Feb.	2.072	3.206	6.41	.521	3.34	3.07
Mar.	2.391	3.699	5.29	.805	4.26	1.03
Apr.	3.812	5.898	6.45	1.020	6.58	−0.13
May	1.559	2.412	4.00	.695	2.78	1.22
June	0.736	1.107	3.12	.407	1.27	1.85
July	0.126	0.194	1.16	.193	0.22	0.94
Aug.	0.287	0.444	4.70	.109	0.51	4.19
Sept.	0.305	0.471	4.36	.121	0.53	3.83
Oct.	0.179	0.276	1.32	.242	0.32	1.00
Nov.	0.193	0.298	2.34	.142	0.33	2.01
Dec.	0.426	0.659	3.64	.209	0.76	2.88
Year	*1.064*	*1.643*	*47.12*	*.465*	*21.92*	*25.20*
1910.						
Jan.	2.425	3.751	7.97	.543	4.33	3.64
Feb.	0.888	1.374	6.88	.208	1.43	5.45
Mar.	3.687	5.705	1.60	4.110	6.57	−4.97
Apr.	2.891	4.473	5.36	.931	4.99	0.37
May	1.397	2.161	3.58	.696	2.49	1.09
June	1.195	1.849	3.70	.557	2.06	1.64
July	0.134	0.207	1.67	.143	0.24	1.43
Aug.	0.251	0.388	4.48	.010	0.45	4.03
Sept.	0.194	0.300	3.07	.109	0.33	2.74
Oct.	0.131	0.202	0.72	.325	0.23	0.49
Nov.	0.452	0.699	5.59	.139	0.78	4.81
Dec.	0.262	0.405	1.87	.250	0.46	1.41
Year	*1.159*	*1.793*	*46.49*	*.524*	*24.36*	*22.13*

YIELD OF SOUTHWEST BRANCH OF MANHAN RIVER. — *Continued.*

Month.	Per Sq. Mile.		Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
	M.G.D.	C.F.S.				
1911.						
Jan.	0.354	0.574	2.08	.296	0.62	1.46
Feb.	0.209	0.323	1.80	.183	0.33	1.47
Mar.	1.306	2.020	4.21	.540	2.27	1.94
Apr.	1.761	2.724	2.61	1.137	2.97	−0.36
May	0.566	0.875	1.13	.872	0.98	0.15
June	0.856	1.324	4.21	.342	1.44	2.77
July	0.422	0.653	4.17	.176	0.73	3.44
Aug.	0.404	0.625	6.71	.105	0.70	6.01
Sept.	0.294	0.455	4.57	.108	0.49	4.08
Oct.	2.433	3.764	8.86	.478	4.24	4.62
Nov.	1.352	2.092	2.57	.887	2.28	0.29
Dec.	1.026	1.587	2.98	.600	1.79	1.19
Year	*0.915*	*1.461*	*45.90*	*.410*	*18.84*	*27.06*
1912.						
Jan.	0.729	1.128	3.65	.356	1.300	2.350
Feb.	0.698	1.080	3.12	.373	1.165	1.955
Mar.	2.663	4.115	5.39	.880	4.744	0.646
Apr.	3.045	4.718	3.26	1.645	5.263	−2.003
May	1.733	2.676	4.60	.671	3.085	1.515
June	0.461	0.713	0.80	.884	0.795	0.005
July	0.151	0.234	2.43	.111	0.269	2.161
Aug.	0.218	0.337	4.96	.078	0.388	4.572
Sept.	0.211	0.326	3.375	.107	0.363	3.012
Oct.	0.725	1.121	5.79	.223	1.293	4.497
Nov.	1.017	1.578	4.24	.415	1.760	2.480
Dec.	1.124	1.732	4.70	.425	1.997	2.703
Year	*1.065*	*1.646*	*46.315*	*.484*	*22.422*	*23.893*
1913.						
Jan.	1.735	2.692	3.61	.860	3.104	0.506
Feb.	0.901	1.394	2.32	.626	1.452	0.868
Mar.	3.026	4.687	5.78	.935	5.403	0.377
Apr.	2.126	3.295	3.95	.931	3.676	0.274
May	1.317	2.042	5.19	.454	2.355	2.835
June	0.374	0.578	0.67	.961	0.644	0.026
July	0.110	0.170	1.88	.104	0.196	1.684
Aug.	0.066	0.102	2.37	.049	0.117	2.253
Sept.	0.203	0.314	3.44	.102	0.351	3.089
Oct.	0.738	1.142	6.77	.194	1.316	5.454
Nov.	0.665	1.025	3.74	.306	1.143	2.597
Dec.	0.934	1.445	3.06	.544	1.666	1.394
Year	*1.061*	*1.574*	*42.78*	*.501*	*21.423*	*21.357*
1914.						
Jan.	0,528	0.817	3.21	.293	0.942	2.268
Feb.	0.835	1.292	5.65	.238	1.345	4.305
Mar.	2.388	3.697	4.32	.987	4.262	0.058
Apr.	3.715	5.755	5.13	1.252	6.421	−1.291
May	2.007	3.109	4.005	.897	3.595	0.410
June	0.302	0.467	2.01	.259	0.521	1.489
July	0.291	0.450	3.18	.163	0.519	2.661
Aug.	0.161	0.249	3.20	.089	0.286	2.914
Sept.	0.073	0.113	0.185	.681	0.126	0.059
Oct.	0.119	0.184	2.03	.105	0.213	1.817
Nov.	0.239	0.370	3.32	.124	0.413	2.907
Dec.	0.295	0.456	3.14	.167	0.526	2.614
Year	*0.912*	*1.413*	*39.38*	*.487*	*19.169*	*20.211*

YIELD OF SOUTHWEST BRANCH OF MANHAN RIVER.—*Continued.*

Month.	Per Sq. Mile. M.G.D.	Per Sq. Mile. C.F.S.	Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
1915.						
Jan.	1.586	2.459	6.605	.429	2.835	3.770
Feb.	2.211	3.419	.5.575	.637	3.560	2.015
Mar.	1.121	1.733	0.15	13.313	1.997	−1.847
Apr.	1.751	2.707	3.97	.760	3.020	0.950
May	0.939	1.453	2.27	.738	1.676	0.594
June	0.351	0.543	2.43	.249	0.606	1.824
July	2.111	3.264	8.96	.420	3.763	5.197
Aug.	2.917	4.517	9.82	.530	5.208	4.612
Sept.	0.353	0.546	2.08	.293	0.609	1.471
Oct.	0.309	0.478	2.01	.274	0.551	1.459
Nov.	1.450	2.243	3.41	.734	2.502	0.908
Dec.	1.450	2.243	.5.42	.479	2.586	2.834
Year	*1.377*	*2.130*	*52.70*	*.549*	*28.913*	*23.787*
1916.						
Jan.	1.577	2.444	1.81	1.557	2.818	−1.008
Feb.	2.953	4.564	6.44	.769	4.923	1.517
Mar.	1.578	2.444	2.83	.995	2.818	0.012
Apr.	3.922	6.064	4.44	1.524	6.766	−2.326
May	1.619	2.506	3.24	.892	2.889	0.351
June	1.549	2.398	5.89	.454	2.676	3.214
July	0.670	1.036	5.42	.220	1.194	4.226
Aug.	0.313	0.484	2.06	.271	0.558	1.502
Sept.	0.494	0.764	8.04	.106	0.853	7.187
Oct.	0.376	0.582	1.55	.434	0.672	0.878
Nov.	0.810	1.253	3.79	.368	1.399	2.391
Dec.	0.926	1.433	2.97	.556	1.653	1.317
Year	*1.387*	*2.164*	*48.48*	*.599*	*29.219*	*19.261*
1917.						
Jan.	1.134	1.748	4.57	.441	2.015	2.555
Feb.	0.572	0.885	2.36	390	0.921	1.439
Mar.	2.116	3.280	4.19	.902	3.781	0.409
Apr.	2.378	3.682	2.24	1.834	4.109	−1.869
May	1.941	3.001	3.40	1.018	3.460	−0.060
June	1.571	2.429	5.23	.518	2.710	2.520
July	0.425	0.657	1.84	.411	0.757	1.083
Aug.	0.202	0.312	3.07	117	0.360	2.710
Sept.	0.116	0.179	0.72	.277	0.200	0.520
Oct.	0.975	1.508	9.37	.186	1.739	7.631
Nov.	0.564	0.872	1.03	.963	0.974	0.056
Dec.	0.479	0.741	4.30	.199	0.854	3.446
Year	*1.042*	*1.608*	*42.32*	*.517*	*21.880*	*20.440*
1918.						
Jan.	0.462	0.715	3.81	.216	0.825	2.985
Feb.	0.900	1.392	1.85	.784	1.450	0.400
Mar.	3.247	5.028	1.58	3.669	5.797	−4.217
Apr.	2.253	3.481	2.90	1.339	3.884	−0.984
May	1.249	1.934	2.86	.779	2.230	0.630
June	0.538	0.832	4.30	.216	0.929	3.371
July	0.273	0.422	2.88	.169	0.486	2.394
Aug.	0.260	0.402	3.84	.121	0.463	3.377
Sept.	0.519	0.803	6.67	.134	0.897	5.773
Oct.	0.275	0.425	1.43	.342	0.489	0.941
Nov.	0.521	0.806	2.93	.307	0.900	2.030
Dec.	1.003	1.547	3.47	.514	1.783	1.687
Year	*0.960*	*1.482*	*38.52*	*.523*	*20.133*	*18.387*

YIELD OF SOUTHWEST BRANCH OF MANHAN RIVER. — *Continued.*

Month.	Per Sq. Mile.		Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
	M.G.D.	C.F.S.				
1919.						
Jan.	0.957	1.480	2.30	.724	1.766	0.594
Feb.	0.503	0.788	3.25	.251	10.820	2.430
Mar.	2.853	4.409	6.13	.829	5.082	1.048
Apr.	1.996	3.094	2.54	1.360	3.455	−0.915
May	2.519	3.898	8.38	.536	4.493	3.887
June	0.786	1.216	1.75	.775	1.357	0.393
July	0.350	0.541	4.66	.134	0.625	4.035
Aug.	0.213	0.329	3.00	.126	0.378	2.622
Sept.	0.451	0.698	4.02	.193	0.779	3.241
Oct.	0.332	0.514	2.56	.232	0.593	1.967
Nov.	1.296	2.011	5.75	.390	2.244	3.506
Dec.	1.006	1.562	2.06	.875	1.802	0.258
Year	*1.110*	*1.712*	*46.40*	*.503*	*23.334*	*23.066*

WATUPPA POND SUPPLY STREAMS, FALL RIVER, MASS.

These records, furnished by Prof. H. K. Barrows, consulting engineer, of Boston, Mass., are published as much because of the light which they shed on the variations to be expected in the run-off of very small adjacent drainage basins as for their intrinsic value for water-works estimates; furthermore, it so happens that in this case two independent investigations have been made covering the same streams, both by able engineers, thus affording a comparison between two independent sets of results.

The records obtained in the first series of studies are contained in the report of Arthur T. Safford to the Reservoir Commission of the City of Fall River, published July, 1902. The results are summarized in the JOURNAL of the N. E. W. W. Association, Vol. 33, pages 326–329, and the rainfall records are discussed in the JOURNAL of the N. E. W. W. Association, Vol. 33, page 61.

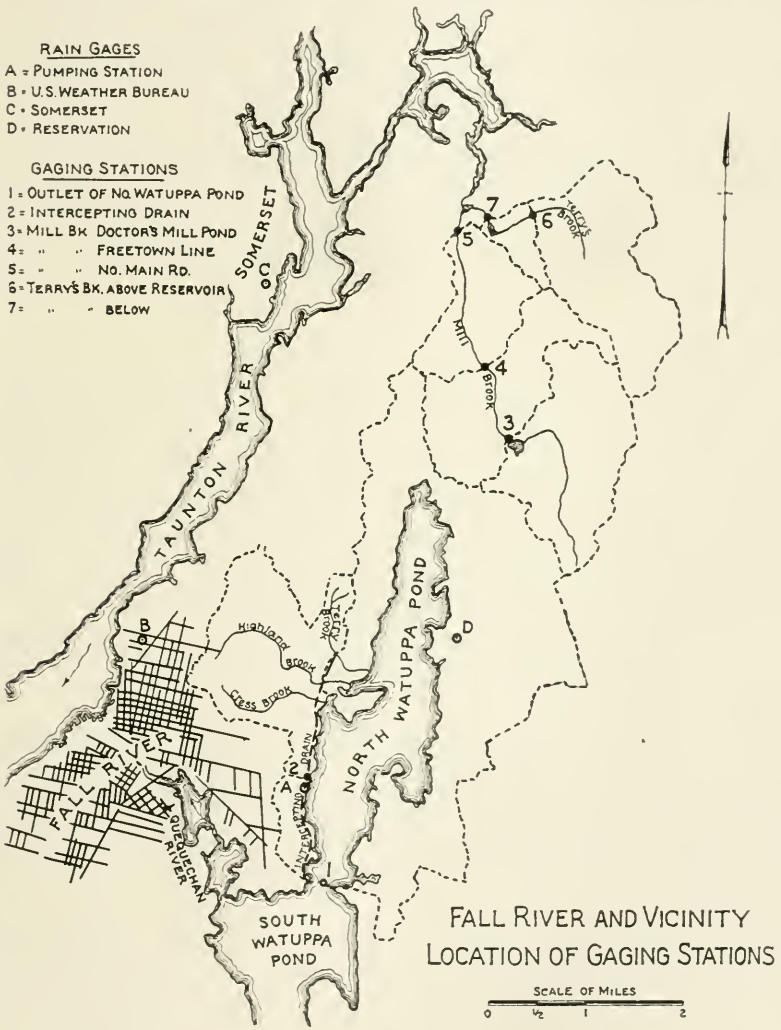
The accompanying map and notes show the locations of the weirs and rainfall stations used in the later investigations. It will be noted that there are considerable differences in the depth of run-off of adjacent basins or adjacent weirs, subject to practically the same precipitation. Similar differences were found in the earlier investigations by Professor Safford, and are undoubtedly due in some degree at least to watershed leakage from higher to lower levels, since in general the lower lying basins show the larger yields, particularly in the Safford results. This in spite of the fact that the lower lying basins were often more swampy, and would apparently be subject to greater water losses.

The location and topography of the various drainage basins are shown on the Fall River, Mass., sheet of the U. S. Geological Survey, topographic maps.

Memorandum Accompanying Data of Run-off and Precipitation for Stations in Vicinity of Fall River, Mass.

General Note.

The location of rain gages and gaging stations is shown on accompanying map. The stream-gaging stations have been maintained under the direction of the Reservoir Commission of the City of Fall River, and the



records furnished through their courtesy by H. K. Barrows, consulting engineer. The precipitation stations in the vicinity of North Watuppa Pond, viz., at the pumping station and reservation, are also maintained by the Reservoir Commission. The other precipitation stations, viz., at Fall River and Somerset, are maintained by the U. S. Weather Bureau.

Precipitation Records.

Precipitation records for 1916 to 1919, inclusive, are shown on appended sheet. As will be noted, there is considerable difference in the recorded results at these several stations. In making studies in this vicinity, as a rule the precipitation records at the pumping station have been used, as these are carefully kept and the exposure of the gage is fairly good. The gage on the Reservation has only been in use a little over a year, but so far seems to indicate a somewhat higher precipitation than that at the pumping station. In general, also, the Weather Bureau gage at Fall River shows a higher precipitation than that observed at the pumping station.

The Somerset gage has a very poor exposure, with several obstructions in the way of trees and buildings quite close to it. The Weather Bureau gage at Fall River is better located, but not entirely free from the effect of obstructions in the vicinity. The Reservation gage is well located in a large field.

Gaging Stations.

Intercepting Drain near Pumping Station. In 1915, an intercepting drain, chiefly of reinforced concrete, was built along the west shore of North Watuppa Pond, as shown on the map, to divert directly to the South Watuppa Pond drainage from the Highland, Terry, and Cress Brook districts. Beginning with 1917, records of the flow through the drain have been obtained by weir measurements at a point near the pumping station, where the drainage area is 1.94 square miles. The weir is placed centrally in a section of the intercepting drain which is open and 10 ft. wide, the crest of the weir being 10 in. above the invert of the drain. For the larger flows current meter measurements have been made, and a rating curve developed.

This drainage area is about two thirds wooded, with either trees or bushes, about one sixth cultivated land with buildings and streets, and the remaining one sixth is swamp area. The underlying soil is hard pan and fairly impervious. Care was taken in constructing the intercepting drain to prevent as far as possible any seepage of water under the drain to the North Pond.

Mill Brook Gaging Stations. The drainage area of Mill Brook is almost entirely wooded, with a little swamp area, most of which is above the Doctor's Mill Pond weir. The underlying soil is sand in the form of glacial drift, although at some little depth the sand becomes very fine, with traces of clay.

Doctor's Mill Pond Weir. Measurements are made by a sharp crested weir placed in the flume of the old dam. There is some leakage by the weir, which is measured by means of a small auxiliary triangular notch weir. The drainage area at Doctor's Mill Pond weir is 1.88 sq. mi.

PRECIPITATION — FALL RIVER VICINITY, 1916–19, INCLUSIVE.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1916.													
Pumping Station	1.17	4.72	3.22	4.29	4.31	3.72	9.85	2.20	1.06	2.11	1.93	4.65	43 53
U. S. Weather Bureau	1.18	5.14	3.77	4.78	4.78	3.90	11.47	2.03	1.28	3.01	3.11	3.71	48.49
Somerset	1.11	4.39	2.92	4.00	3.74	4.29	10.66	1.31	1.12	2.29	2.79	3.11	42.06
1917.													
Pumping Station	2.44	2.91	5.08	3.33	4.98	4.79	1.33	3.03	2.89	4.67	0.37	2.03	37.85
U. S. Weather Bureau	3.63	2.73	5.04	3.17	4.77	4.63	1.21	3.75	2.93	5.69	0.45	3.10	41.10
Somerset	2.87	2.55	3.87	3.04	5.20	4.33	1.12	3.95	2.95	5.95	0.24	1.80	37.87
1918.													
Pumping Station	3.17	2.86	2.04	1.92	1.90	3.06	2.71	3.14	3.55	0.82	2.00	3.19	33.96
U. S. Weather Bureau	4.01	3.56	2.46	5.51	2.00	3.24	2.51	3.98	4.42	1.08	2.32	4.08	39.17
Somerset	3.33	2.88	2.52	4.09	1.72	2.40	3.16	2.08	3.81	0.90	2.02	2.71	31.65
1919.													
Pumping Station	5.53	3.77	3.90	3.00	4.18	2.08	5.06	6.41	6.81	2.12	3.88	2.89	49.63
U. S. Weather Bureau	5.07	3.80	5.29	3.24	4.62	1.93	5.52	7.26	7.48	2.51	3.71	2.33	52.76
Somerset	4.76	3.87	4.22	3.04	4.30	1.84	5.47	6.74	7.10	2.82	4.07	2.54	46.47
Reservation	5.18	4.05	5.22	3.56	5.19	2.33	5.41	7.57	6.45	2.46	1.52	2.72	54.66

YIELD AT TERRY'S BROOK NO. 1, ABOVE RESERVOIR, FALL RIVER, MASS.
Drainage Area, 1.83 Sq. Mi.

Month.	Mean C.F.S.	Per Sq. Mile.		Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss. In.	Per Cent. Run-off.
		M.G.P.	C.F.S.				
1917.							
Jan.	4.00	1.41	2.19	2.44	2.52	−0.08	1.04
Feb.	3.00	1.06	1.64	2.91	1.70	1.21	.59
Mar.	7.23	2.55	3.95	5.08	4.55	0.53	.12
Apr.	6.47	2.29	3.54	3.33	3.94	−0.61	1.18
May	5.57	1.96	3.04	4.98	3.51	1.47	.71
June	5.22	1.85	2.85	4.79	3.18	1.61	.66
July	0.84	0.30	0.46	1.33	0.53	0.80	.40
Aug.	0.42	0.15	0.23	3.03	0.27	2.76	.09
Sept.	0.22	0.08	0.12	2.89	0.14	2.75	.05
Oct.	1.23	0.43	0.67	4.67	0.77	3.90	.17
Nov.	1.19	0.42	0.65	0.37	0.72	−0.35	1.96
Dec.	1.86	0.66	1.02	2.03	1.17	0.86	.58
Year	*3.10*	*1.10*	*1.70*	*37.85*	*23.00*	*14.85*	*.608*
1918.							
Jan.	2.13*	0.75*	1.17*	3.17	1.34*	1.83*	.42
Feb.	4.14	1.46	2.26	2.86	2.35	0.51	.82
Mar.	2.85	1.01	1.56	2.04	1.79	0.25	.88
Apr.	5.12	1.81	2.80	4.92	3.12	1.80	.64
May	2.72	0.96	1.49	1.90	1.72	0.18	.91
June	1.28	0.45	0.70	3.06	0.78	2.28	.26
July	0.32	0.11	0.18	2.71	0.20	2.51	.08
Aug.	0.23	0.08	0.13	3.44	0.15	3.29	.05
Sept.	0.21	0.07	0.11	3.55	0.13	3.42	.04
Oct.	0.10	0.03	0.05	0.82	0.06	0.76	.08
Nov.	0.31	0.11	0.17	2.00	0.19	1.81	.10
Dec.	1.82	0.65	1.00	3.49	1.15	2.34	.33
Year	*1.77*	*0.62*	*0.97*	*33.96*	*12.98*	*20.98*	*.382*
1919.							
Jan.	4.05	1.43	2.21	5.53	2.55	2.98	.46
Feb.	5.04	1.78	2.76	3.77	2.87	0.90	.76
Mar.	6.75	2.38	3.69	3.90	4.25	−0.35	1.09
Apr.	5.31	1.87	2.90	3.00	3.24	−0.24	1.08
May	5.4	1.91	2.95	4.18	3.40	0.78	.82
June	...	...	...	2.08	...	...	...
July	...	...	...	5.06	...	...	...
Aug.	...	...	...	6.41	...	...	...
Sept.	...	...	...	6.81	...	...	...
Oct.	...	...	...	2.12	...	...	...
Nov.	...	...	...	3.88	...	...	...
Dec.	...	...	...	2.89	...	...	...
Year	...	...	...	*49.63*	...	...	...

* Estimated.

Mill Brook at Freetown Line. Measurements in general have been made by current meter and rating curve, although in the low water season a triangular notch weir has been used most of the time. Drainage area, 3.35 sq. mi.

Mill Brook at North Main Road. Measurements made by current meter and rating curve, except a portion of the time during a low water season, when a 2-ft. rectangular weir is used. Drainage area, 4.39 sq. mi.

Terry's Brook Gaging Stations. The drainage area is nearly all wooded, with a small amount of swamp and water area.

Terry's Brook No. 1, above the Reservoir. Measurements were made partly by current meter and rating curve and partly by weir. Drainage area, 1.83 sq. mi.

Terry's Brook No. 2, below the Reservoir. Measurements made by current meter and rating curve. The station is about 100 ft. below the spillway of the upper reservoir of the Crystal Spring Bleachery, a small reservoir used simply for storage purposes. Drainage area, 2.19 sq. mi.

All these records are published as taken, without reduction to basis of yield of net land area.

YIELD AT TERRY'S BROOK NO. 2, CRYSTAL SPRINGS, BELOW RESERVOIR, FALL RIVER MASS.

Drainage Area, 2.19 Sq. Mi.

Month.	Mean C.F.S.	Per Sq. Mile.		Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss. In.	Per Cent. Run-off.
		M.G.P.	C.F.S.				
1917.							
Jan.	4.19	1.23	1.91	2.44	2.20	0.24	.90
Feb.	2.70	0.79	1.23	2.91	1.29	1.62	.45
Mar.	6.23	1.83	2.84	5.08	3.28	1.80	.65
Apr.	5.56	1.64	2.54	3.33	2.82	0.51	.85
May.	5.48	1.62	2.50	4.98	2.88	2.10	.58
June.	4.77	1.41	2.18	4.79	2.43	2.36	.51
July.	1.23	0.36	0.56	1.33	0.65	0.68	.49
Aug.	1.04	0.31	0.47	3.03	0.55	2.48	.18
Sept.	1.62	0.48	0.74	2.89	0.83	2.06	.29
Oct.	1.15	0.34	0.53	4.67	0.61	4.06	.13
Nov.	1.62	0.48	0.74	0.37	0.82	−0.45	2.22
Dec.	1.67	0.49	0.76	2.03	0.88	1.15	.44
Year.	*3.11*	*0.92*	*1.42*	*37.85*	*19.24*	*18.61*	*.508*
1918.							
Jan.	3.01	0.89	1.37	3.17	1.58	1.59	.50
Feb.	4.38	1.29	2.00	2.86	2.08	0.78	.73
Mar.	3.66	1.08	1.67	2.04	1.93	0.11	.95
Apr.	4.61	1.36	2.10	4.92	2.35	2.57	.48
May.	2.40	0.71	1.10	1.90	1.26	0.64	.66
June.	1.08	0.32	0.49	3.06	0.53	2.53	.17
July.	0.51	0.15	0.23	2.71	0.27	2.44	.10
Aug.	0.18	0.05	0.08	3.44	0.10	3.34	.03
Sept.	0.31	0.09	0.14	3.55	0.16	3.39	.05
Oct.	0.18	0.05	0.08	0.82	0.09	0.73	.11
Nov.	0.00	0.00	0.00	2.00	0.00	2.00	0.00
Dec.	1.57	0.46	0.72	3.49	0.83	2.66	.24
Year.	*1.82*	*0.54*	*0.83*	*33.96*	*11.18*	*22.78*	*.328*
1919.							
Jan.	6.33	1.87	2.89	5.53	3.34	2.19	.60
Feb.	5.09	1.50	2.32	3.77	2.42	1.35	.64
Mar.	6.47	1.91	2.96	3.90	3.42	0.48	.88
Apr.	5.33	1.57	2.43	3.00	2.71	0.29	.90
May.	4.51	1.33	2.06	4.18	2.38	1.80	.57
June.	...	...	...	2.08	...	...	...
July.	...	...	...	5.06	...	...	...
Aug.	...	...	...	6.41	...	...	...
Sept.	...	...	...	6.81	...	...	...
Oct.	...	...	...	2.12	...	...	...
Nov.	...	...	...	3.88	...	...	...
Dec.	...	...	...	2.89	...	...	...
Year.	...	...	...	*49.63*	...	...	...

YIELD OF MILL BROOK AT DOCTOR'S MILL POND WEIR, FALL RIVER, MASS.
Drainage Area, 1.88 Sq. Mi.

Month.	Mean C.F.S.	Per Sq. Mile.		Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss In.	Per Cent. Run-off.
		M.G.P.	C.F.S.				
1916.							
Jan.	2.56	0.88	1.36	1.47	1.57	−0.10	1.07
Feb.	2.52	0.87	1.34	4.72	1.45	3.27	.31
Mar.	4.00	1.38	2.13	3.22	2.46	0.76	.77
Apr.	6.04	2.08	3.22	4.29	3.59	0.70	.84
May	5.92	2.04	3.15	4.31	3.64	0.67	.84
June	5.08	1.75	2.70	3.72	3.02	0.70	.81
July	7.81	2.69	4.15	9.85	4.79	5.06	.49
Aug.	2.27	0.78	1.21	2.20	1.40	0.80	.64
Sept.	0.29	0.10	0.15	1.06	0.17	0.89	.16
Oct.	0.64	0.22	0.34	2.11	0.39	1.72	.19
Nov.	0.88	0.30	0.47	1.93	0.52	1.41	.27
Dec.	2.52	0.87	1.34	4.65	1.54	3.11	.33
Year.	*3.38*	*1.16*	*1.80*	*43.53*	*24.54*	*18.99*	*.564*
1917.							
Jan.	3.33	1.14	1.77	2.44	2.04	0.40	.84
Feb.	2.29	0.79	1.22	2.91	1.27	1.64	.44
Mar.	6.67	2.29	3.55	5.08	4.08	1.00	.80
Apr.	6.51	2.23	3.46	3.33	3.86	−0.53	1.16
May	6.03	2.07	3.21	4.98	3.68	1.30	.74
June	5.10	1.75	2.71	4.79	3.02	1.77	.63
July	1.20	0.41	0.64	1.33	0.73	0.60	.55
Aug.	0.41	0.14	0.22	3.03	0.25	2.78	.08
Sept.	0.35	0.12	0.19	2.89	0.21	2.68	.07
Oct.	1.53	0.52	0.81	4.67	0.94	3.73	.20
Nov.	1.43	0.49	0.76	0.37	0.85	−0.48	2.31
Dec.	1.82	0.63	0.97	2.03	1.11	0.92	.55
Year.	*3.06*	*1.05*	*1.63*	*37.85*	*22.04*	*15.81*	*.582*
1918.							
Jan.	2.68*	0.92*	1.42*	3.17	1.64*	1.53	.52
Feb.	7.74*	2.66*	4.12*	2.86	4.29*	−1.43	1.50
Mar.	4.72	1.62	2.51	2.04	2.90*	−0.86	1.42
Apr.	6.41	2.20	3.41	4.92	3.80	1.12	.77
May	3.16	1.08	1.68	1.90	1.94	−0.04	1.02
June	1.61	0.55	0.85	3.06	0.96	2.10	.32
July	0.44	0.15	0.23	2.71	0.27	2.44	.10
Aug.	0.54	0.19	0.29	3.44	0.33	3.11	.10
Sept.	0.31	0.11	0.16	3.55	0.18	3.37	.05
Oct.	0.27	0.09	0.14	0.82	0.17	0.65	.22
Nov.	0.59	0.20	0.31	2.00	0.35	1.65	.18
Dec.	2.08	0.72	1.11	3.49	1.28	2.21	.37
Year.	*2.56*	*0.87*	*1.35*	*33.96*	*18.11*	*15.81*	*.533*
1919.							
Jan.	4.59	1.58	2.44	5.53	2.82	2.71	.51
Feb.	4.24	1.45	2.25	3.77	2.35	1.42	.63
Mar.	6.48	2.23	3.44	3.90	3.97	−0.07	1.02
Apr.	5.48	1.88	2.82	3.00	3.26	−0.26	1.09
May	5.17	1.78	2.75	4.18	3.18	1.00	.76
June	1.23	0.42	0.65	2.08	0.73	1.35	.35
July	1.58	0.54	0.84	5.06	0.97	4.09	.19
Aug.	2.15	0.74	1.14	6.41	1.32	5.09	.21
Sept.	5.89	2.02	3.13	6.81	3.50	3.31	.51
Oct.	1.97	0.68	1.05	2.12	1.21	0.91	.57
Nov.	3.28	1.12	1.74	3.88	1.95	1.93	.50
Dec.	4.84	1.66	2.57	2.89	2.97	−0.08	1.03
Year.	*3.90*	*1.34*	*2.07*	*49.63*	*28.23*	*21.40*	*.569*

* Estimated.

YIELD OF MILL BROOK AT NORTH MAIN ROAD, ASSONET, FALL RIVER, MASS.
Drainage Area, 4.39 Sq. Mi.

Month.	Mean C.F.S.	Per Sq. Mile.		Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss. In.	Per Cent. Run-off.
		M.G.P.	C.F.S.				
1916.							
Jan.	...	...	...	1.47	...	...	...
Feb.	...	...	...	4.72	...	...	...
Mar.	...	...	...	3.22	...	...	...
Apr.	...	...	...	4.29	...	...	...
May	12.4	1.83	2.83	4.31	3.26	1.05	.76
June	10.7	1.58	2.44	3.72	2.72	1.00	.73
July	17.6	2.59	4.00	9.85	4.61	5.24	.47
Aug.	4.45	0.65	1.01	2.20	1.17	1.03	.53
Sept.	0.90	0.13	0.20	1.06	0.23	.83	.22
Oct.	1.89	0.28	0.43	2.11	0.50	1.61	.24
Nov.	2.32	0.34	0.53	1.93	0.59	1.34	.31
Dec.	6.05	0.89	1.38	4.65	1.59	3.06	.34
Year.	...	...	...	*43.53*	...	...	...
1917.							
Jan.	8.92	1.31	2.03	2.44	2.34	0.10	.96
Feb.	6.14	0.90	1.40	2.91	1.45	1.46	.50
Mar.	15.45	2.27	3.52	5.08	4.06	1.02	.80
Apr.	12.87	1.89	2.93	3.33	3.27	0.06	.98
May	11.89	1.75	2.70	4.98	3.12	1.86	.63
June	11.39	1.68	2.60	4.79	2.89	1.90	.60
July	2.24	0.33	0.51	1.33	0.59	0.74	.45
Aug.	0.68	0.10	0.16	3.03	0.18	2.85	.06
Sept.	0.84	0.12	0.19	2.89	0.21	2.68	.07
Oct.	3.27	0.48	0.74	4.67	0.86	3.81	.19
Nov.	3.02	0.45	0.69	0.37	0.77	−0.40	2.08
Dec.	9.60	1.42	2.19	2.03	2.52	−0.49	1.25
Year.	*7.19*	*1.06*	*1.64*	*37.85*	*22.26*	*15.59*	*.588*
1918.							
Jan.	7.14*	1.05*	1.62*	3.17	1.88*	1.29	.59
Feb.	20.73	3.05	4.72	2.86	4.92	−2.06	1.72
Mar.	10.79	1.59	2.46	2.04	2.83	−0.79	1.39
Apr.	14.82	2.18	3.38	4.92	3.77	1.15	.77
May	6.56	0.96	1.49	1.90	1.72	0.18	.91
June	3.06	0.45	0.70	3.06	0.78	2.28	.26
July	0.77	0.11	0.18	2.71	0.20	2.51	.08
Aug.	0.87	0.13	0.20	3.44	0.23	3.21	.07
Sept.	0.77	0.11	0.17	3.55	0.19	3.36	.06
Oct.	0.64	0.09	0.15	0.82	0.17	0.65	.21
Nov.	1.55	0.23	0.35	2.00	0.39	1.61	.20
Dec.	4.67	0.69	1.06	3.49	1.22	2.27	.35
Year.	*6.03*	*0.89*	*1.37*	*33.96*	*18.30*	*15.66*	*.539*
1919.							
Jan.	14.81	2.18	3.37	5.53	3.89	1.64	.70
Feb.	13.22	1.94	3.01	3.77	3.14	0.63	.83
Mar.	14.44	2.12	3.29	3.90	3.79	0.11	.97
Apr.	12.08	1.77	2.75	3.00	3.06	−0.06	1.01
May	11.6	1.71	2.64	4.18	3.05	1.13	.73
June	...	...	...	2.08	...	...	...
July	...	...	...	5.06	...	...	...
Aug.	...	...	...	6.41	...	...	...
Sept.	...	...	...	6.81	...	...	...
Oct.	...	...	...	2.12	...	...	...
Nov.	...	...	...	3.88	...	...	...
Dec.	...	...	...	2.89	...	...	...
Year.	...	...	...	*49.63*	...	...	...

* Estimated.

YIELD AT WEIR ON FALL RIVER, INTERCEPTING DRAIN NEAR PUMPING STATION, FALL RIVER, MASS.

Drainage Area, 1.94 Sq. Mi.

Month.	Mean C.F.S.	Per Sq. Mile.		Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss. In.	Per Cent. Run-off.
		M.G.P.	C.F.S.				
1917.							
Jan.	2.74	0.91	1.41	2.44	1.62	0.82	.67
Feb.	2.22	0.74	1.14	2.91	1.19	1.72	.41
Mar.	6.80	2.27	3.51	5.08	4.04	1.04	.80
Apr.	5.24	1.74	2.70	3.33	3.02	0.31	.91
May	5.50	1.83	2.84	4.98	3.28	1.70	.66
June	4.42	1.47	2.28	4.79	2.55	2.24	.53
July	1.14	0.38	0.59	1.33	0.68	0.65	.52
Aug.	0.554	0.19	0.29	3.03	0.33	2.70	.11
Sept.	0.43	0.14	0.22	2.89	0.25	2.64	.09
Oct.	1.48	0.49	0.76	4.67	0.88	3.79	.19
Nov.	1.34	0.45	0.69	0.37	0.77	−0.40	2.08
Dec.	1.61	0.54	0.83	2.03	0.95	1.08	.47
Year.	*2.79*	*0.93*	*1.44*	*37.85*	*19.56*	*18.29*	*.517*
1918.							
Jan.	2.06*	0.68*	1.06*	3.17	1.23*	1.94	.39
Feb.	3.74*	1.25*	1.93*	2.86	2.00*	0.86	.70
Mar.	4.01	1.33	2.06	2.04	2.38	−0.34	1.17
Apr.	5.72	1.90	2.94	4.92	3.28	1.64	.67
May	2.44	0.82	1.26	1.90	1.46	0.44	.77
June	1.12	0.37	0.58	3.06	0.65	2.41	.21
July	0.28	0.09	0.14	2.71	0.17	2.54	.07
Aug.	0.41	0.14	0.21	3.44	0.24	3.20	.07
Sept.	0.23	0.08	0.12	3.55	0.13	3.42	.04
Oct.	0.14	0.05	0.07	0.82	0.09	0.73	.11
Nov.	0.43	0.14	0.22	2.00	0.25	1.75	.13
Dec.	1.42	0.47	0.73	3.49	0.84	2.65	.24
Year.	*1.83*	*0.61*	*0.94*	*33.96*	*12.72*	*21.24*	*.375*
1919.							
Jan.	4.12	1.37	2.12	5.53	2.44	3.09	.44
Feb.	4.27	1.42	2.20	3.77	2.29	1.48	.61
Mar.	6.86	2.29	3.54	3.90	4.08	−0.18	1.05
Apr.	5.28	1.75	2.71	3.00	3.04	−0.04	1.01
May	4.50	1.50	2.32	4.18	2.68	1.50	.64
June	0.98	0.33	0.51	2.08	0.57	1.51	.27
July	1.23	0.42	0.63	5.06	0.73	4.33	.15
Aug.	2.35	0.78	1.21	6.41	1.40	5.01	.22
Sept.	5.70	1.91	2.94	6.81	3.28	3.53	.48
Oct.	2.23	0.74	1.15	2.12	1.32	0.80	.63
Nov.	4.48	1.49	2.31	3.88	2.58	1.30	.67
Dec.	3.30	1.10	1.70	2.89	1.96	0.93	.68
Year.	*3.77*	*1.25*	*1.94*	*49.63*	*26.37*	*23.26*	*.531*

* Estimated.

YIELD OF MILL BROOK AT FREETOWN LINE, FALL RIVER, MASS.
Drainage Area, 3.35 Sq. Mi.

Month.	Mean C.F.S.	Per Sq. Mile.		Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss. In.	Per Cent. Run-off.
		M.G.P.	C.F.S.				
1916.							
Jan.	...	...	...	1.47	...	...	...
Feb.	...	...	...	4.72	...	...	...
Mar.	...	...	...	3.22	...	...	...
Apr.	...	...	...	4.29	...	...	...
May.	10.9	2.00	3.25	4.31	3.75	0.56	.87
June.	8.41	1.63	2.51	3.72	2.80	0.92	.76
July.	14.0	2.70	4.18	9.85	4.82	5.03	.49
Aug.	3.90	0.75	1.16	2.20	1.34	0.86	.61
Sept.	0.55	0.10	0.16	1.06	0.18	0.88	.17
Oct.	1.07	0.21	0.32	2.11	0.37	1.74	.18
Nov.	1.49	0.29	0.45	1.93	0.50	1.43	.26
Dec.	4.54	0.88	1.36	4.65	1.57	3.08	.34
Year.	...	...	...	*43.53*	...	...	...
1917.							
Jan.	6.01	1.16	1.79	2.44	2.07	0.37	.85
Feb.	3.52	0.68	1.05	2.91	1.10	1.81	.38
Mar.	12.04	2.31	3.59	5.08	4.14	0.94	.82
Apr.	10.96	2.11	3.27	3.33	3.65	−0.32	1.10
May.	10.86	2.09	3.24	4.98	3.73	1.25	.75
June.	9.41	1.81	2.81	4.79	3.13	1.66	.65
July.	1.84	0.36	0.55	1.33	0.63	0.70	.48
Aug.	0.84	0.16	0.25	3.03	0.29	2.74	.10
Sept.	0.71	0.14	0.21	2.89	0.24	2.65	.04
Oct.	2.88	0.56	0.86	4.67	0.99	3.68	.27
Nov.	2.56	0.49	0.76	0.37	0.85	−0.48	2.30
Dec.	3.13	0.60	0.93	2.03	1.08	0.95	.53
Year.	*6.01*	*1.04*	*1.61*	*37.85*	*21.90*	*15.95*	*.578*
1918.							
Jan.	4.8*	0.93*	1.44*	3.17	1.66*	1.51	.53
Feb.	11.9*	2.30*	3.56*	2.86	3.71*	−0.85	1.30
Mar.	7.57	1.46	2.26	2.04	2.61	−0.57	1.28
Apr.	10.92	2.11	3.26	4.92	3.64	1.28	.74
May.	6.25	1.21	1.87	1.90	2.15	−0.25	1.14
June.	2.58	0.50	0.77	3.06	0.86	2.20	.28
July.	0.57	0.11	0.17	2.71	0.20	2.51	.08
Aug.	0.81	0.16	0.24	3.44	0.28	3.16	.08
Sept.	0.48	0.09	0.14	3.55	0.16	3.39	.05
Oct.	0.40	0.08	0.12	0.82	0.14	0.68	.18
Nov.	0.97	0.19	0.29	2.00	0.32	1.68	.16
Dec.	4.08	0.79	1.22	3.49	1.41	2.08	.41
Year.	*4.28*	*0.83*	*1.28*	*33.96*	*17.14*	*16.82*	*.505*
1919.							
Jan.	10.03	1.94	3.00	5.53	3.46	2.07	.63
Feb.	7.08	1.37	2.12	3.77	2.21	1.56	.59
Mar.	10.50	2.02	3.13	3.90	3.62	0.28	.93
Apr.	10.07	1.94	3.00	3.00	3.36	−0.36	1.12
May.	12.55	2.42	3.75	4.18	4.32	−0.14	1.04
June.	...	...	...	2.08	...	...	...
July.	...	...	...	5.06	...	...	...
Aug.	...	...	...	6.41	...	...	...
Sept.	...	...	...	6.81	...	...	...
Oct.	...	...	...	2.12	...	...	...
Nov.	...	...	...	3.88	...	...	...
Dec.	...	...	...	2.89	...	...	...
Year.	...	...	...	*49.63*	...	...	...

* Estimated.

Evaporation from Water Surfaces.

It was the intention of the committee to present, in conjunction with its report, available records of evaporation from water surfaces. Inasmuch, however, as a new Committee on Water Losses has been appointed by the New England Water Works Association, which will undoubtedly consider matters of evaporation in detail, and since the existing records would apparently require more discussion than would be appropriate here, to render them available for practical use, they have been omitted.

The following references to existing records of evaporation from water surfaces may, however, prove useful:

Rochester, N. Y.

This record gives the result of evaporation as measured in two fiber tubs, each 15 in. top diameter, 7½ in. deep, and with water surface about 3 in. below the rim. One tub is floated in Mt. Hope Reservoir, surrounded by a raft; the other tub stands on the raft. The available records for the floating tub cover generally the months April to October in the years 1891 to 1896, inclusive, and are complete for all months in subsequent years. The record for the tub exposed on the raft covers the months April to November, inclusive, from 1891 to date, with the exception of the first four years, for which certain months are missing. The records are accompanied by data showing mean temperature of water in each tub, rainfall, air temperature, and for the years subsequent to 1905 wind velocity is also given. The earlier results have been published in the annual reports of the Executive Board of the City of Rochester, and the later results in the reports of the Department of Engineering, Rochester, N. Y.

Maine Stations.

Records of evaporation at Millinocket, Lewiston, Mooselookmeguntic, Me., and Soldier Pond, Me., for summer periods in the years 1905 to 1908 inclusive, are contained in Water Supply Paper No. 279, "Water Resources of the Penobscot River Basin, Maine," by H. K. Barrows and C. C. Babb, pages 113–129. These records were obtained by means of floating pans, protected by raft, the pans being 3 ft. square and 18 in. deep. Weekly results are given, accompanied by data of water and air temperature, humidity, and wind velocity.

Boston, Mass.

Records of evaporation at Chestnut Hill Reservoir, Boston, and experimental data to determine the laws of evaporation, are contained in a paper by Desmond FitzGerald, Mem. Am. Soc. C. E., Trans. Am. Soc., Vol. 15, September, 1886, pages 581–646; also in a paper, "Rainfall, Flow of Streams, and Storage," same author, Trans. Am. Soc. C. E., Vol. 27, 1892.

Graefenburg Reservoir, Utica, N. Y.

Records of evaporation obtained from a 3-ft. square buried tank, depth 24 in., with rim 3 in. above ground, and water, covering the summer months of the years 1905–6–7, are given in the reports of the state engineer and surveyor of New York State, 1906 Supplement, pages 215–245, and 1907 report, pages 518–532.

Hartford, Conn.

Records of evaporation from land and floating pans are maintained under the direction of Caleb M. Saville, chief engineer, Board of Water Supply, Hartford, Conn. Results not published.

Gardiner, Me.

Evaporation for a Class A U. S. Weather Bureau Station, with circular pan 4 ft. in diameter and 8 in. deep, land exposed, supported on grillage, has been maintained at Gardiner, Me., during the months May to October, inclusive, beginning July, 1915, and continuing to date. The results are published monthly in Climatological Data, U. S. Weather Bureau.

Albany, N. Y.

A Class A land-exposed U. S. Weather Bureau standard evaporation pan is maintained at Voorheesville, N. Y., near Albany, N. Y., under the direction of Robert E. Horton. The record covers the summer months of the years 1918 to date. The pan is circular, 4 ft. in diameter and 8 in. deep, supported on grillage — readings taken by micrometer hook gage. Records of air and water surface temperatures, humidity, and wind velocity are also maintained. Records not published.

Discussion.

Mr. Caleb M. Saville. Does Mr. Horton say that his committee did not go into the matter of water losses? If I heard correctly, he said he did not. I wish that he would tell us something about water losses, because I know of no one who has made a more thorough or more complete study than Mr. Horton.

The one question that I should like to ask, perhaps, to start the discussion, but not to start discussion wholly on the mooted question of water supply, is this: Other things being equal, which is better, a water supply from ground covered with various trees, say with forty-year-old chestnut and mixed hardwoods, or one covered with scrub and sprouts after the timber has been cut off? I am thinking now of losses that come from evaporation. This I am sure is an interesting question to some of us, which has particularly come up in connection with the question of deforestation of our watersheds.

Mr. Horton. In regard to going into the matter of water losses: The committee has gone into it just to this extent, of making the simple subtraction of the annual or monthly run-off each month from the corresponding precipitation. We have not attempted to analyze this water loss. We have confined ourselves strictly, as a committee, to those two matters, — the collection of available records and the attempt to set forth, as we have done in the conclusions of the report, our ideas as to methods of obtaining and presenting run-off statistics which would give in the simplest manner possible reliable records, and records on a fairly uniform basis. I have not the slightest objection to going into the very interesting questions which Mr. Saville has propounded, but were I to undertake to do so, I should say that the only proper procedure would be to take off my coat and hammer away at it myself, as other members of the committee may possibly have different views.

I will state very briefly some things which possibly may cover the main points from my own point of view, without committing myself too definitely at this time. The questions which Mr. Saville has raised are some of the most perplexing questions, and they are questions to which no universal answer can be given by "yes" or "no." The conditions are different in different localities, and the answer will be different in different localities.

What I think is generally meant by water losses is all deductions from rainfall which occur through natural processes, especially those deductions in a water-tight drainage basin where all the rain that isn't lost goes down the stream sooner or later. Those deductions I have often classified as of three kinds. A considerable portion of rainfall over a forested area never reaches the ground, and at the same time my own experience indicates that in average showers the percentage may be 25 per cent., and averages 20 per cent. probably. It does not vary very much with the kind of trees, whether beeches, birches, maple, pine, or hemlocks. About 20 per cent. of the rain does not reach the ground at all. If the rain came in a very heavy storm every time it rained, there would be a much smaller percentage. But rain does not come that way in the Eastern states. It comes in average amounts of a third of an inch per rain-day.

The second point is evaporation from the soil. The evaporation from the soil is very much less — is very much less in a cropped field than a bare field, if the soil condition is the same. It is more in a cropped field than it is in a forest.

The third source of loss is from what has percolated through the soil and is drawn up in the roots of the plants and is passed out through transpiration through the leaves. That loss is relatively large. It amounts for a growing crop to perhaps ten or twelve or fourteen inches a year, but if there isn't that amount of water in the soil, a corn crop, for instance, will get along with a great deal less amount of water. So you see that the problem has many ramifications to which no general answer can be given.

Suppose the soil is of a good quality and available for agricultural uses. It was originally covered with a heavy forest of broad-leaved trees. Then, as the country was settled, the forest was cut away. Possibly there was more or less swamp which was drained. Then Mr. Water Works Man comes along and says to the municipality, "Now, let us buy this watershed, and we will control this ourselves." And, so far as the protection from pollution goes, it is a mighty good proposition, but usually there goes with it another feature which appeals strongly to the popular mind: "We will re-forest that area." But in most cases I am afraid that the answer to that should be "no." I may be wrong, and I may have to change my views on that point, and I wish to say here that I shall possibly change my view when more experimental data is at hand. We are trying to get some of these answers from some of these records that you are keeping and preparing.

But, just to take an illustration, which I have not cooked up in advance at all: In your original forested area you would have a loss out of 36 in. of rain of perhaps 9 in. by interception; you would have a loss by evaporation from the soil of perhaps 4 in., and you would have a loss by transpiration of perhaps 7 in. That would mean that there would be 20 in. of losses, leaving 16 in. out of your 36, or 16 in. of run-off, and that is the condition you would get there.

When the forest is cleared off and the land is under cultivation, with good farming land and productive growing crops like clover, corn, or potatoes, with rotation of grains, you would have an interception loss which would be greatly reduced, perhaps to 4 in. instead of 9. You would have evaporation from the soil considerably increased; probably 9 in. instead of 4. You would have a transpiration loss of probably 10 or 12 in., — say, 10 in., — so that you would have a total loss in that case of 23 in. as compared with the loss of 20 in. from the forested area.

But now take the other situation: If the water department purchased this drainage basin and bought out the farms, and the farmers moved away, and the land was allowed to run wild, to a certain extent, and simply grown up to wild grass and not put under forestation. Then you would have a still smaller interception, perhaps not more than 2 in. Perhaps you would have 12 in. of evaporation loss. Your transpiration loss would be cut way down to perhaps 5 or 6 in. So that probably you would have as small water losses, and very likely smaller, than from the original forest, and, so far as the conservation of water is concerned, the bare tract of land would yield more water than the forested area.

MR. SAVILLE. What I had particularly in mind was that in our Connecticut areas, and in Massachusetts also, we have been having very serious conditions, due to chestnut blight. Large areas that were once covered with chestnut trees have been cut off and laid bare after the blight struck them. The question has arisen as to whether it is better to cut all of the hardwoods as well, and then re-forest with other trees. It might be

tried on a strip of perhaps 50 or 60 acres. Then plant that, perhaps, with young trees of some quickly growing variety that will grow in five or six years. My thought was whether that growth was as well, or better perhaps, than the former growth that was there, so far as water supply is concerned.

Mr. H. N. Blunt.* Twenty years ago the watershed of each of our streams was very heavily wooded, but they are now being very rapidly cut off, and we are wondering what is going to happen, because there is no effort to re-forest, and all over the watershed brush has grown up, and instead of having a big umbrella, there is a scrub growth. We are much concerned with what will happen during the dry seasons. Mr. Horton did not touch on that feature of the problem, which may affect some of us, but it is certainly an interesting subject.

Mr. Horton. I have given a good deal of thought to that question. The question seems to me this, essentially: "What is the difference between the heavy, dense forest and the scrub forest and woods in the forest by which it may be replaced after it is burned over or cut?" I am very sorry that I cannot help you definitely, because the data are so meager that it is only by careful study of the matter of transpiration of different kinds of trees that a judgment can be formed. It is possible by careful study of existing results that reliable judgment might be formed, but I should hate to give an off-hand judgment of it. There are some places in Switzerland that have been keeping records in this regard, but there is no station in the United States where this information has been collected and kept. This question of yours involves especially the relative transpiration losses for small and large trees. I would say that as far as I can go would be this: Young plants generally transpire water more readily and rapidly in proportion to the weight of dry matter produced in the plant than does a maturer or older plant. On the other hand, the transpiring surface is much smaller. Just how that balance will work, I am unable to say.

* Superintendent Water Company, Palmerton, Pa.

REPORT OF THE JOINT COMMITTEE ON STANDARD SPECIFICATIONS FOR WATER METERS.

The Joint Committee of the American and New England Water Works Associations, on Standard Specifications for Water Meters, submits its final report, accompanied by a draft of Standard Specifications for Cold-Water Meters, Disc Type, which it recommends for adoption; a statement of the information which should be furnished to meter manufacturers when requesting bids under the proposed specifications; a description of the equipment necessary to test meters for compliance with the registration and capacity requirements of the specifications; and a statement of tests recommended.

Appointment, Organization, and Meetings of Committee. The formation of a committee on meter specifications was suggested by Mr. R. J. Thomas, who presented a brief paper to the convention of the New England Water Works Association at Portland, Me., in 1916, calling attention to the desirability of uniform standard specifications for meters. Following the presentation of that paper it was voted that a committee of the New England Water Works Association be appointed.

In 1919, upon the representation of members of the New England Association's committee to the American Association, the latter voted to appoint a similar committee, which was done forthwith.

The first actual meeting of the Joint Committee, or of either of the committees appointed by the associations, was held on March 9 and 10, 1920. Prior to that time such progress as had been made was accomplished by correspondence.

It was immediately decided to organize as a Joint Committee, and to make a single report to both associations. The committee organized with Charles W. Sherman as chairman and Seth M. Van Loan as secretary.

At the conclusion of the meeting of March 9 and 10, 1920, a subcommittee consisting of Messrs. Saville, Brush, Van Loan, and McMurry, was appointed, to give further consideration to points raised in the main committee, to carry out certain experimental work, and to obtain some further information from the manufacturers, and to report back to the Joint Committee at a later date.

The second and concluding meeting of the Joint Committee was held February 8 and 9, 1921, at which time the draft of the specifications was tentatively adopted and the form of the report considered. The final work of the committee has been accomplished by correspondence.

Preliminary Work of New England Water Works Association Committee. Correspondence between the members of the New England

Association's committee began soon after the original appointment in 1916, but before anything of significance had been accomplished the United States entered the World War and it became impracticable for the members of the committee to devote any material amount of time to committee work. Late in 1917, however, the Department of Water Supply, Gas, and Electricity of New York City prepared a tentative draft of specifications, under the direction of Mr. W. W. Brush, a member of the committee. After further correspondence between the members of the committee it was planned to print these tentative specifications as a basis for discussion, and submit them to the 1918 convention of the New England Water Works Association, as a progress report; but before this was done information from the manufacturers indicated that certain points in the tentative draft should be discussed with the manufacturers before submitting them to any convention, and the draft was therefore not circulated.

Draft of Specifications Prepared by Meter Manufacturers. During 1918 and 1919 the manufacturers of water meters held a series of conferences under the auspices of the Meter Manufacturers' Exchange, — but to which manufacturers not members of that exchange were invited, — at which they discussed the subject of specifications and finally prepared a draft of standard specifications acceptable to all of them. These conferences were held in New York City, and during the latter part of the time were attended by Mr. W. W. Brush, as representative of the New England Association's committee. They concluded in February, 1920, when a draft of standard specifications acceptable to the manufacturers was completed.

The Meter Manufacturers' Exchange includes the Buffalo Meter Company, Hersey Manufacturing Company, Neptune Meter Company, Pittsburgh Meter Company, Thomson Meter Company, Union Water Meter Company, and Worthington Pump and Machinery Company. Other manufacturers not members of the Exchange are Badger Meter Company, Gamon Meter Company, and National Meter Company. It is the understanding of the committee that all of the manufacturers were either represented at the conferences or subsequently assented to the action taken at those meetings.

The specifications thus drafted and submitted to the Joint Committee of the Water Works Associations covered both the disc and current types of meter.

Work of the Joint Committee. Following receipt from the manufacturers of their draft on a standard specification, the Joint Committee met on March 9 and 10, 1920, as above noted, and proceeded to analyze and discuss the specifications submitted by the manufacturers.

It was at once decided to limit the committee's work to specifications for disc meters, for several reasons, the most potent being that substantially all of the meters likely to be bought under competitive bidding

belong to this class. It was also felt that if standard specifications for disc meters were adopted, after they had been in use a number of years the experience with them would indicate more clearly than can now be anticipated, the kind of specifications which should be prepared to cover other classes of meters.

During the year 1920 the subcommittee continued the investigation of various questions left unsettled by the Joint Committee, and finally reported back to the committee a revised draft of specifications, a statement of information which should be furnished to bidders in asking for bids under the specifications, a description of the tests necessary to determine whether meters complied with the specifications, and a list of the minimum equipment with which such tests could be made.

At the final meeting of the committee, on February 8 and 9, 1921, the material submitted by the subcommittee was discussed in detail and amended in some minor particulars, and then referred back to the subcommittee for submission to the manufacturers. Further slight modifications have been made as a result of comments by manufacturers, and the material as thus finally revised has been accepted by the committee, through correspondence.

Acknowledgment. In presenting the proposed specifications to the two associations for their consideration, the Joint Committee wishes particularly to acknowledge its indebtedness to the meter manufacturers, who showed throughout an earnest desire to coöperate and to comply with all reasonable requirements, and particularly to standardize details of construction with the object of making meters of various makes interchangeable in service, without rearrangement of connections.

Respectfully submitted,

For the Joint Committee,

CHARLES W. SHERMAN, *Chairman.*

William W. Brush, *Chairman.*
Charles W. Sherman,
A. W. F. Brown,
R. J. Thomas,
N. E. W. W. Ass'n Committee.

Henry V. Macksey,
James A. McMurry,
John H. Walsh,

Caleb M. Saville, *Chairman.*
Dow R. Gwinn,
R. J. Thomas,
Seth M. Van Loan,
Am. W. W. Ass'n Committee.

APRIL 7, 1921.

STANDARD SPECIFICATIONS FOR COLD-WATER METERS, DISC TYPE.

Cases. All meters shall have an outer case with a separate inner chamber in which the disc operates. The outer case for all 2-in. and smaller meters shall be of bronze composition. Cast-iron frost bottoms may be provided. The outer case for meters larger than 2 in. shall be of bronze composition or of cast iron protected by a non-corrosive treatment.

All meters shall have cast on them in raised characters the size and the model, and the direction of the flow through the meter shall be properly indicated. Meters larger than 1 in. shall be designed for easy removal of all interior parts, without disturbing the connections to the pipe line.

External Bolts. All external bolts shall be made of bronze or of galvanized iron or steel. Nuts shall be designed for easy removal after having been long in service.

Registers. Registers may be either " round " or " straight " reading, indicating in cubic feet or gallons.

All parts of the registers shall be made of non-ferrous material. The maximum indication of the initial dial, and the minimum capacity of the register when indicating cubic feet, shall be as follows:

Size. Inches.	Maximum Indication of Initial Dial. Cubic Feet.	Minimum Capacity of Register. Cubic Feet.
$\frac{5}{8}$	1	100 000
$\frac{3}{4}$	10	1 000 000
1	10	1 000 000
$1\frac{1}{2}$	10	1 000 000
2	10	10 000 000
3	10	10 000 000
4	100	100 000 000
6	100	100 000 000

All dials, including the initial dial, shall be subdivided into ten equal parts. All hands or pointers shall taper to a sharp point. They shall be accurately set and securely held in place.

Register Boxes. Register boxes and lids shall be made of bronze composition or same material as the top case, with the name of the manufacturer cast on the lid in raised letters. The serial number of the meter shall be plainly stamped on the lid. If required, the serial number shall also be stamped on the case. The lid shall be recessed and shall lap over the box to prevent dirt from accumulating on the glass. The glass shall be inserted from the inside and securely held in place without the use of putty or pins. All register compartments shall be provided with a water-

escape hole $\frac{1}{8}$ in. in diameter, placed so that the change gear or registering mechanism cannot be tampered with.

Connections. $\frac{5}{8}$-in., $\frac{3}{4}$-in. and 1-in. Sizes. Spuds shall be threaded $\frac{3}{4}$, 1, and $1\frac{1}{4}$ in. respectively, male thread, standard pipe size, and so threaded that Briggs Standard pipe thread ring gages may be screwed on by hand within one thread of through the gage.

Over-all lengths of meters, face to face of spuds, shall be —

$\frac{5}{8}$-in. — $7\frac{1}{2}$ in.
$\frac{3}{4}$-in. — 9 in.
1-in. — $10\frac{3}{4}$ in.

Couplings shall be made of bronze composition. Nuts shall be tapped $\frac{3}{4}$ in., 1 in. and $1\frac{1}{4}$ in. respectively, straight thread, standard pipe size, and so tapped that Briggs Standard pipe thread plug gages may be backed into the nuts by hand; i. e., the size of the thread in the nut is the maximum size of the Briggs plug, but no larger. Tailpieces shall be threaded $\frac{1}{2}$, $\frac{3}{4}$ and 1 in. respectively, male thread, standard pipe size, and so threaded that Briggs Standard pipe thread ring gages may be screwed on by hand, flush with the face of the gage.

Over-all lengths of tailpieces shall be —

$\frac{5}{8}$-in. — $2\frac{3}{8}$ in.
$\frac{3}{4}$-in. — $2\frac{1}{2}$ in.
1-in. — $2\frac{5}{8}$ in.

Connections. $1\frac{1}{2}$ in. and 2 in. Sizes. Spuds shall be tapped $1\frac{1}{2}$ and 2 in. respectively, female thread, standard pipe size, and so tapped that Briggs Standard pipe thread plug gages may be screwed on by hand up to the notch on the plug.

Over-all lengths of meters, face to face of spuds, shall be —

$1\frac{1}{2}$-in. — $12\frac{5}{8}$ in.
2-in. — $15\frac{1}{4}$ in.

Couplings shall be made of bronze composition. Nuts shall be tapped 2 in. and $2\frac{1}{2}$ in. respectively, straight thread, standard pipe size, and so tapped that Briggs Standard pipe thread plug gages may be backed into the nuts by hand; i. e., the size of the thread in the nut is the maximum size of the Briggs plug, but no larger. Tailpieces shall be threaded $1\frac{1}{2}$ in. and 2 in. respectively, male thread, standard pipe size, and so threaded that Briggs Standard pipe thread ring gages may be screwed on by hand flush with the face of the gage; 2 by $1\frac{1}{2}$ in. and $2\frac{1}{2}$ by 2 in. standard pipe size malleable-iron bushings are to be furnished with $1\frac{1}{2}$ in. and 2-in. couplings respectively. Care shall be taken to see that nuts as above described can be screwed on to the bushings by hand, and that the face of the bushings will be sufficiently true and square to provide a proper packing surface.

Over-all lengths of tailpieces shall be —

$1\frac{1}{2}$-in. — $2\frac{7}{8}$ in.
2-in. — 3 in.

Connections. 3-in., 4-in. and 6-in. Sizes. Spuds shall be flanged, faced and drilled. Companion flanges shall be of cast iron, faced, drilled and tapped. All dimensions, drilling and tapping, shall conform exactly to American standard of January 1, 1914.

Over-all lengths of meters, face to face of flanges, shall be —

3-in. — 24 in.
4-in. — 29 in.
6-in. — $36\frac{1}{2}$ in.

Seal Wire Holes. $\frac{5}{8}$-in., $\frac{3}{4}$-in., 1-in., $1\frac{1}{2}$-in. and 2-in. meters shall have register box screws and coupling nuts drilled for seal wire holes. Meters larger than 2 in. in size shall have register box screws drilled for seal wire holes. All seal wire holes shall not be less than $\frac{3}{32}$ in. in diameter.

Measuring Chambers. The measuring chamber for all meters shall be made of bronze composition and shall not be cast as part of the outer casing. It shall be machined with great care and secured in position in the outer casing so that any slight distortion of the casing which might take place under 150-lb. working pressure will not affect the sensitiveness of the meter.

Discs. Disc pistons shall be made of vulcanized rubber, and shall be fitted accurately but freely in their chambers. Vulcanized rubber pistons shall have a metal reinforcement or a thrust roller.

Intermediate Gear Trains. The intermediate gear trains shall be of such construction as to be easily removed, and shall be made throughout of non-ferrous material. Gear spindles may run in bearings bushed with hard rubber, provided the bushings are so constructed that they cannot drop out.

Strainers. All meters shall be provided with strainers except when self-strained by means of an annular space between the measuring chamber and the external case. Strainers shall be made of non-ferrous materials and shall fit tightly against the wall of the casing. They shall have an effective straining area as large as practicable and at least double that of the inlet.

Registration. The registration on the meter dial shall indicate the quantity recorded to be not less than 98 per cent. nor more than 102 per cent. of the water actually passed through the meter while it is being tested at rates of flow within the limits specified herein under "normal test-flow limits." There shall be not less than 90 per cent. of the actual flow recorded when a test is made at the rate of flow set forth under "minimum test-flow."

Size, Inches.	Normal Test-Flow Limits, Gallons per Minute.	Minimum Test-Flow, Gallons per Minute.
$\frac{5}{8}$	1 to 20	$\frac{1}{4}$
$\frac{3}{4}$	2 to 34	$\frac{1}{2}$
1	3 to 53	$\frac{3}{4}$
$1\frac{1}{2}$	5 to 100	$1\frac{1}{2}$
2	8 to 160	2
3	16 to 315	4
4	28 to 500	7
6	48 to 1 000	12

Capacity. New meters shall show a loss of head not exceeding 25 lb. per square inch, when the rate of flow is that given in the following table:

Size, Inches.	Gallons per Minute.
$\frac{5}{8}$	20
$\frac{3}{4}$	34
1	53
$1\frac{1}{2}$	100
2	160
3	315
4	500
6	1 000

Pressure Test. Disc meters shall be guaranteed to operate under a working pressure of 150 lb. per sq. in., without leakage or damage to any part.

Workmanship and Material. Disc meters shall be guaranteed against defects in materials and workmanship, for a period of one year from date of shipment. Parts to replace those in which a defect may develop within such period shall be supplied without charge, piece for piece, upon the return of such defective parts to the manufacturer thereof or upon proper proof of such defect.

Rejected Meters. The manufacturer shall, at his own expense, replace or satisfactorily readjust all meters rejected for failure to comply with these specifications.

Information to be Furnished to Meter Manufacturers when Requested to submit Bids on Disc Meters.

1. Meters shall conform to the Standard Specifications for Cold-Water Meters, Disc Type, adopted by the American and New England Water Works Associations.

2. The manufacturer shall state in his bid the type of meter he proposes to furnish, as listed in his catalogue, The actual capacity of each size of meter called for is to be given graphically from 0 lb. up to 25 lb. loss of pressure. If this capacity be stated in the manufacturer's catalogue, reference may be made thereto.

3. No bid will be considered on meters of a design which has not been listed for at least one year in the catalogue regularly issued by the manufacturer.

4. The method of testing meters shall conform to that recommended by the Committee on Standard Specifications for Water Meters.

5. (*a*)* The meters are to be accepted on a certificate furnished by the manufacturer, that the meters have met the requirements of the Standard Specifications for Water Meters, as adopted by the American and New England Water Works Associations.

(*b*)* The meters will be tested by the purchaser to determine whether they do or do not comply with the Standard Specifications for Water Meters adopted by the American and New England Water Works Associations.

6. Registers shall be {round / straight} reading, and shall record in {cubic feet / gallons.}

Equipment Necessary to Test Meters for Compliance with Registration and Capacity Requirements, as set forth in the Standard Specifications for Water Meters.

The standard specifications require that meters shall accurately record the flow within certain limits and shall pass a given quantity of water with a maximum loss of pressure. Suitable equipment to make accurate tests must be available before the purchaser should make complaint of meters not complying with the specifications.

The minimum test equipment required for registration and capacity is as follows:

1. A quick-acting valve on the supply pipe through the use of which the flow can be started and stopped without appreciable loss of time.

2. A valve on the outlet side of the meter which can be used to establish the rate of flow desired.

3. Pressure gages connected on both the inlet and outlet of the meter to show whether any material change in pressure occurs during the period of test which would affect the rate of flow. (The outlet pipe is to have sufficient head on it so that the meter will always have pressure on its outlet end and preferably not less than 5 lb. per sq. in.)

4. A measuring device which may be either of the volumetric or weighing type. Whichever is used, the accuracy of determination of the volume or weight of water discharged into the measuring device must be such as to bring the limit of error within one tenth of 1 per cent. (The volume of water passed must be sufficient to cause at least one or more revolutions of the pointer on the initial dial, except for tests at "minimum test-flow" rate. For the latter test, the amount passed shall not be less than one cubic foot.)

It is desirable to have available for testing meters a test table and appurtenances which are manufactured by several concerns. Such an

* *Note.* Sentence (*a*) is to be used where the purchaser does not have suitable equipment to test the meters. If he has such equipment then sentence (*b*) is to be used.

outfit would include the equipment enumerated in the preceding four paragraphs.

For the capacity tests, it is necessary to add to the above equipment, 2 piezometer rings which must be of exactly the same diameter. The piezometer rings must be free from any burrs where the holes are drilled through the wall of the ring, and not less than four holes shall be provided, drilled in pairs and on diameters at right angles to one another. The inlet piezometer ring shall be set close to the meter, and shall be at a distance of not less than eight diameters from the nearest upstream stop-cock or fitting in the supply pipe. The outlet piezometer ring shall be placed at a distance of not less than 8 nor more than 10 diameters from the outlet of the meter. The diameter of the piezometer rings and inlet and outlet pipes shall be the same as the size of the meter to be tested. The piezometer rings are to be connected by either rubber or metal tubing to a mercury U-tube. To this U-tube is to be attached an accurate adjustable scale for measuring the differences between the inlet and outlet pressures. Provision is to be made for the complete removal of air from the tubing connected with the U-tube, and the U-tube and the tubing connected therewith is to be so placed that the air will rise to the outlets. Where relatively high flows are to be recorded, it is necessary to read both sides of the mercury column to compensate, as far as practicable, for irregularities in the diameter of the glass U-tube, and such readings are to be made as nearly simultaneously as possible to avoid errors due to fluctuations.

Tests of Meters Recommended.

The tests to be made on the meter are divided into two classes:

1. Capacity test.
2. Registration test.

Capacity tests are those which test the design of the meter rather than the workmanship thereof. When a meter of a given make has once been tested for capacity, it should not be necessary to again test this type of meter unless a change has been made in its design.

The registration tests should be made on each meter, as the results are affected by workmanship and assembly of individual meters. There is no certainty that, because one meter of a given make comes within certain limits of accuracy, another meter of the same make turned out by the factory on the same day will necessarily give similar results. The register furnished with each meter should be used by both the manufacturer and purchaser in making registration tests. Where the purchaser does not have the necessary equipment to test the meters, there should be furnished by the manufacturer a certificate that each meter has been tested for accuracy of registration and complies with the standard specifications in this respect, and that the type of meter furnished has complied with the capacity requirements.

The registration tests recommended are as follows:

All meters should be tested for accuracy of registration within and as near as practicable to the low and high rates given under "Normal Test-Flow Limits."

A test at the "Minimum Test-Flow" should be made on as many as possible, and not less than 5 per cent. of the meters. If the results obtained from testing 5 per cent. of the meters show that any meter does not comply with the low-flow requirement, additional meters should be tested to the extent deemed necessary to make certain that the other meters do comply therewith.

The pressure test should be made on each size of meter furnished of a particular type. This pressure is to be 150 lb. per sq. in., and the pressure may be furnished through the use of a hand pump or such other method as may be available. Before the meter has been tested by static pressure, and also after it has been so tested, it should be tested for accuracy to see whether the meter has been so distorted as to affect registration. It is considered unnecessary to make a pressure test of each size of meter of a given type more than once if satisfactory results are obtained.

If it be possible to give a working-pressure test under 150 lb. per sq. in., then such a test should be applied rather than a static-pressure test.

JAMES P. BACON — PROF. WILLIAM T. SEDGWICK.

FEBRUARY 9, 1921.

THE PRESIDENT. It is my sad duty to call to the attention of the meeting two great losses which we have suffered since our last meeting.

Our well-known stenographer and friend, Mr. James P. Bacon, has passed away. Mr. Bacon has reported the meetings of this Association practically from its beginning, and was well known to a very large number of our members and much beloved by every one who knew him. Although Mr. Bacon was not a member of the Association, I feel that the Association has suffered as much of a loss as it would in the loss of a member. I know his interest was with us, and he was always present when he was able to come.

We have also lost a past president and honorary member, Prof. William T. Sedgwick, and I am going to ask Professor Whipple to say a few words of appreciation of Professor Sedgwick.

Professor Whipple spoke feelingly of Professor Sedgwick's life and work, closing as follows:

This is not the time or the place to tell the whole story of Professor Sedgwick's life. We merely wish to give due honor to his memory and to interrupt our proceedings in order that we may think of him in sweet remembrance.

THE PRESIDENT. May I ask that everyone stand for a moment in silent tribute to the memory of Mr. Bacon and Professor Sedgwick.

[Everybody rises and stands in silence.]

WILLIAM THOMPSON SEDGWICK.

A complete appreciation of the life of William Thompson Sedgwick will never be written except in the hearts of his hundreds of friends. The important milestones in his life are the following:

1855, December 29, born a son of William and Anne Thompson Sedgwick, at West Hartford, Conn.

1877, graduated from the Sheffield Scientific School, Yale University, Ph.B. in biology.

1878, instructor in physiological chemistry at Yale.

1881, graduated from Johns Hopkins University, Ph.D. in biology.

1879–83, fellow, instructor, and associate in biology.

1881, December 29, married Mary Katrine Rice, of New Haven, Conn.

1883, assistant professor of biology, Massachusetts Institute of Technology.

1885, associate professor of biology, M. I. T.

WILLIAM THOMPSON SEDGWICK

1886, joint author of "General Biology."

1888–96, biologist of the Massachusetts State Board of Health.

1891–1921, professor of biology and public health, and director of the Sanitary Research Laboratory, M. I. T.

1897–1921, curator of the Lowell Institute.

1899–1921, trustee of Simmons College.

1900, president of the Society of American Bacteriologists.

1901, president of the American Society of Naturalists.

1902, published "Sanitary Science and Public Health."

1902–1921, member of the Advisory Board of the Hygienic Laboratory of the U. S. Public Health Service.

1906, published, with Theodore Hough, "The Human Mechanism."

1913–1921, chairman of the Administrative Board of the School of Public Health of Harvard University and the Institute of Technology.

1914–1921, member of the Public Health Council of the Massachusetts Department of Health.

1915, president of the American Public Health Association.

1917, published, with H. W. Tyler, "A Short History of Science."

1920, exchange professor at the Universities of Leeds and Cambridge, England, and "ambassador of health" from the American Public Health Association to the Allied Conference at Brussels.

1920, delivered address at the one hundredth anniversary of the Medical School of the University of Cincinnati, and received degree of LL.D.

1921, January 25, died at Boston.

In the above outline of a career full of honor, there is no record of Professor Sedgwick's connection with this Association, and little of his work in the field of water supply.

There have appeared many eulogies describing his various activities as writer and teacher of biological science, as interpreter of the laws of health, as epidemiologist, as wise counselor of state and university, as eloquent lecturer on sanitary science, and as citizen and patriot, but it seems fitting to record here the Association's appreciation of his work in its own field.

Sedgwick was a student at Yale while Pasteur was doing much of his pioneer work in bacteriology, and when Robert Koch discovered the bacillus of anthrax. He was studying at Johns Hopkins University when Eberth discovered the typhoid fever germ, and began his work at the Institute of Technology in 1883, the same year that Koch discovered the germ of cholera. Hitherto his intention had been to become a physician, but with the prescience which was characteristic of his later life, Sedgwick now abandoned this intention and devoted his life to applied biology, thus beginning his professional work when even so eminent a sanitary chemist as William Ripley Nichols was skeptical about the relations between bacteria and water-borne disease.

In the years before 1887, the JOURNAL of the Association contained practically no papers relating to water as such, to methods for determining its quality, or to its relation with water-borne disease. In these regards,

the early years of the Association were years of growth; the year 1887–88 was a year of fruition. In this Sedgwick played an important part. At the meeting held at Young's Hotel on March 12, 1888, he read a paper entitled, "The Biological Examination of Water." This was discussed by E. K. Dunham, Desmond FitzGerald, F. P. Stearns, Samuel W. Abbot, and A. F. Noyes. It was the first presentation to the Association of the conclusions of the new science of bacteriology, the application of which to the art of water supply was stimulated by the Massachusetts Inland Waters Act of 1886, and the work of Walcott, Mills, Sedgwick, Drown, Stearns, and others, serving as officers of the State Board of Health and the Lawrence Experiment Station. Professor Sedgwick was consulting biologist of the Board, and with his colleagues directed the work at Lawrence. The station work was under the immediate direction of Allen Hazen, who was succeeded by George W. Fuller, and he in turn by the present director, Harry W. Clark. It is unnecessary to describe the work of the Lawrence Experiment Station in the fields of water purification and sewage disposal. It stands for itself. The station has been the birthplace of many scientific discoveries, and the nursery of some of the leading sanitary engineers of the country, and both discoverers and engineers owe much of their success to their consulting biologist, — to his knowledge of men and things, and particularly to his ability to emphasize the important, a quality which he possessed to a remarkable degree.

In 1890, an epidemic of typhoid swept down the valley of the Merrimack River, and Sedgwick was detailed to study it. While not possessing the mathematical mind, Sedgwick understood the dramatic use of statistics as did few of his time, and so presented the facts connecting the typhoid fever of the valley cities with the sewage of their respective upstream neighbors, that his conclusions were unassailable. This work led to the Lawrence water filters, designed by Hiram F. Mills, C.E. This, the first scientifically designed filter in America, is, with its additions, although outgrown in size and basis of design, still protecting the citizens of Lawrence against an epidemic like that of 1890.

It was in the field of epidemiology that Sedgwick was at his best as a workman. Not only did he determine the history of several notable epidemics, particularly of water-borne typhoid fever, but, more than that, developed new methods of study which have been used by his followers with success.

Professor Sedgwick joined the New England Water Works Association in 1890, became an honorary member in 1904, and was elected president in 1906. His term of office is remembered as among the most fruitful years of the Association. After the presentation of his first paper in the second volume of the JOURNAL, the following papers and discussions appeared:

Volume IV, "Biological Water Analysis."

Volume V, "Surface Water for Drinking Purposes."

Volume VII, "Sand Filtration."

Volume X, "Sanitary Condition of the Water Supply of Burlington, Vt."

Volume XI, "Organisms Which Cause Unpleasant Odors and Tastes in Water Supplies."

Volume XX, "Responsibility for the Causation of Typhoid Fever."

Volume XX, "Protection of Water Supplies from Pollution by Railroads, with Special Reference to the Supply of Seattle, Wash."

Volume XXV, "Has the Time Come for Municipal Double Service?"

Volume XXV, "Notes on Typhoid Fever at Washington, D. C."

Volume XXX, "Water Supply Sanitation in the Nineteenth Century and in the Twentieth."

Not only was Professor Sedgwick memorable because of his personal contributions to the papers and discussions before this Association, but as a teacher of sanitary engineers. Many of these have reflected the training received at his hands in the literary work of the Association. One has only to recall the names of Allen Hazen, George W. Fuller, Joseph W. Ellms, Stephen DeM. Gage, F. S. Hollis, D. D. Jackson, William S. Johnson, Morris Knowles, M. O. Leighton, Elbert E. Lochridge, Earnest C. Levy, Charles P. Moat, Horatio N. Parker, Gilbert H. Pratt, Charles W. Sherman, Carol T. Storey, W. Lyman Underwood, C.-E. A. Winslow, and others, to realize the influence of his teaching upon the art of water supply as developed by the work of this Association.

After 1914, Professor Sedgwick continued his work for the state as a member of the Committee on Sanitary Engineering of the Public Health Council of the State Department of Public Health.

It was the custom at the Department of Biology and Public Health at the Institute to hold weekly conferences of teachers and students, presided over by the "Chief." The subjects were live and varied, — a new water-purification process, a typhoid epidemic, why so many babies die, public health work in China, the work of the Red Cross expedition to Serbia, why Dr. Blank failed in the West, and others of human and cosmopolitan interest.

In recent years these conferences have included the students of the public health school, coming from the principal countries of the world. At these conferences, criticisms by the "Chief" were candid and personal, often severe, but also kindly. He conquered bumptiousness and bad manners by urbanity and courtesy. Many a rough diamond began its transformation into a gem at these profitable meetings.

His last address before the Association was delivered on September 11, 1918, on the timely subject, "From Peace to War, from War to Victory, from Victory to Just Judgment." This address was delivered at a well-attended meeting, and was heard with sympathetic attention. This address revealed the ripened man, the springs of his character, also his

uncomprising support of stern justice for the worshipers of the tribal God of the Teutons and their Kaiser, and his faith in the Christian ideal of service.

Those who knew Professor Sedgwick as fellow-member, teacher, counselor, leader or friend, will long treasure the influence which he radiated from his lovable and inspiring personality.

His last years and hours indicated his courage and spirit of service. Although suffering for several years from an affection which limited his activities and ultimately caused his death, he unremittingly promoted the welfare of the country and the expeditionary forces during the Great War in many important ways, not the least of which were the emergency training of laboratory workers to take the place of those who had entered the service of the Government, and the work for the refugee children of France. On the last evening of his life, he spoke at a meeting in the interest of education.

With this patriotic work, and in fact with all of the work of his life, Mrs. Sedgwick was closely associated. In the hearts of Professor Sedgwick's students, her personality will always be associated with his.

William Thompson Sedgwick lived honestly and unreservedly. He made no distinction between the sacred and the profane. With him all life was sacred. The God of his heart was the God of his country and the God which his study of science revealed. With him, a beloved member of this Association, a scholar, an interpreter of science, a worthy public servant, and a Christian gentleman has entered the larger life.

Robert Spurr Weston.
George Chandler Whipple.

CHARLES WILLARD YOUNG.

Charles W. Young passed away suddenly at his summer home in St. Stephen, N. B., on the St. Croix River, September 21, 1920. He was born in Calais, Me., November 11, 1858, the son of Benjamin and Rhoda (Stevens) Young.

Mr. Young became a member of this Association in 1915 and while not active took much interest in its progress.

When a young man he became a partner with his father in the lumber firm of Benjamin Young & Son, who carried on extensive operations in Nova Scotia for several years.

Mr. Young was for thirty years president and a large owner of the St. Croix Soap Manufacturing Company and held a large interest in the Calais & St. Stephen Street Railway, and many other enterprises in this section and mining interests in the southwest.

In recent years he became interested in the Warren Brothers Corporation, in the construction of improved roads, and has been an important factor in the great success of their work.

About eight years ago he purchased and fitted up a beautiful home in Winchester, Mass.

His activities in water supply were in the incorporating of the Barnstable Water Company, covering the towns of Barnstable, and Yarmouth on Cape Cod, and has been president of this company since its start in 1912. He was for a time president of the Norton Water Company.

Recently he established in Boston the managing firm of C. W. Young & Sons, in which he was joined by his two sons, Frederic and Kenneth, and they took over the property of the Mercer County Light, Heat and Power Company, also the Pittsburg District Electric Company, and the Barnstable Water Company.

Mr. Young was an enthusiastic curler and was for several years president of the St. Stephen Curling Club; also of the Golf Club. He was a member of the Calais Universalist Church, and the Boston Art Club.

Mr. Young was one of the most lovable of men, a genial companion and an honorable opponent; a man of strong will and great ability, which he exercised freely in the interests of his wide circle of friends. The Association, the community, and the state lose a strong agent for the best in many of the most important of human interests.

He is survived by his wife, two sons, and three daughters, — Mrs. Vera Wadsworth, of Cleveland, Ohio; Mrs. Rhoda Le Royer, of New York, and Mrs. Georgia Farnsworth, of Boston.

Henry A. Symonds.
Hervey A. Hanscom.

RICHARD L. TARR.

Richard L. Tarr, a member of this Association, died October 12, 1920, after more than eighteen months' illness. He was a native of Gloucester, Mass., where he was born March 1, 1880, and was the son of James H. and Elizabeth G. (Burnham) Tarr. He was a descendant of Richard Tarr, the original settler of the name on Cape Ann. He has been connected with the Gloucester Water Department for about twenty years, being first employed in the survey of Haskell's Reservoir in 1901, and was appointed a foreman in 1904, holding the position until the time of his death.

He was a man who was universally liked and esteemed, always having a pleasant greeting for his friends and acquaintances. He is survived by his mother and three brothers — Alfred C., Hardy B., and Philip V. Tarr — and two sisters, Misses Esther and Priscilla Tarr.

Mr. Tarr was elected a member of the New England Water Works Association September 14, 1911.

John W. Moran.
James W. Blackmer.

EDWARD L. HATCH.

Mr. Edward L. Hatch was born in Stamford, Conn., October 16, 1878. He received his early schooling through private tutors and later spent two years at Lakewood.

His first business training was with the Stamford Trust Co., where he remained for several years. In 1905 he became connected with the Stamford Water Company as executive clerk and assistant treasurer in general charge of the office. In November, 1906, he was made general manager, and in December, 1909, was elected a director. He remained director, general manager and assistant treasurer to the time of his death on November 4, 1920.

Mr. Hatch was married on August 4, 1915, to Emma Hurlbut, of Riverside, Conn.

He was very fond of trapshooting and fishing and was an ardent hunter, having at various times visited the West, Canada, Mexico, and Maine on hunting expeditions.

He was a director of the Citizens Savings Bank and the Stamford Yacht Club, and president of the Suburban Club.

He was a member of the Presbyterian Church in Stamford.

Mr. Hatch was very highly regarded in the community on account of his ability, his fine personality, and his courtesy to all. His friends will long mourn his loss.

He died at his home at Shippan Point, of pneumonia, following influenza, after a gallant battle lasting about six weeks.

Mr. Hatch was forty-two years old when he died, and is survived by his wife and twin sons, four years old.

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Yours truly,

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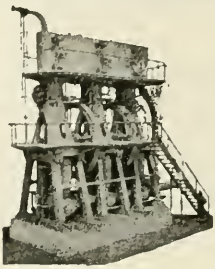
Vertical Triple Pumping Engine
26/48/72 x 19½ x 42
160 *lbs. steam*
200 *lbs. water*
Superheat 114 *F.*
7 *million gallons*
192 *million duty*

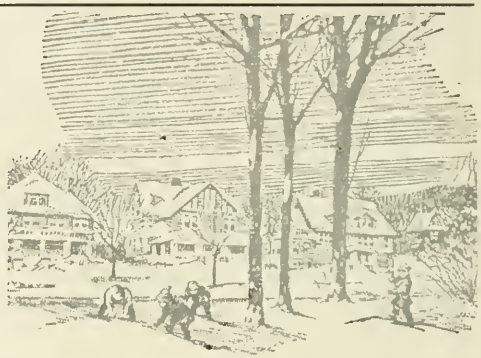


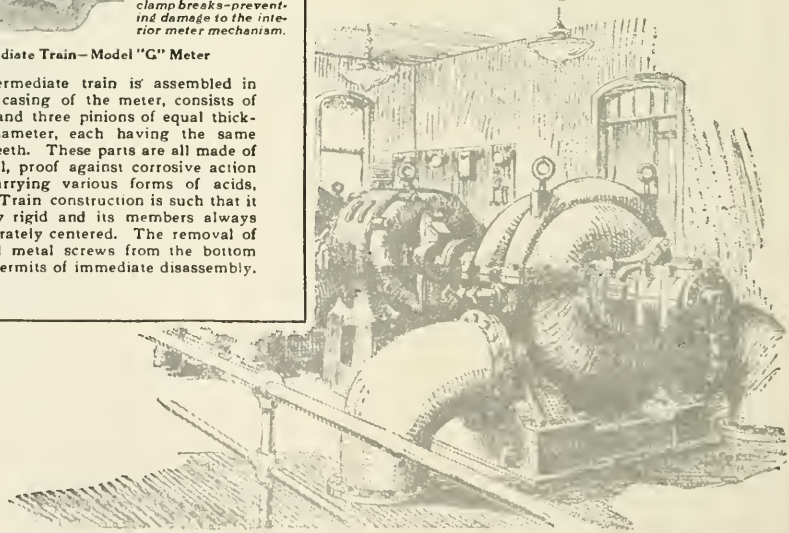
Vertical Triple Pumping Engine
14¾/28/41½ x 12⅛ x 30
150 *lbs. steam*
150 *lbs. water*
2½ *million gallons*
162 *million duty*
Washington, D. C. — 1905
Cleveland, Ohio — 1907

Fitted with long main-flange bolts and cast iron clamps, this model "G" meter is frost proof. Should the meter freeze, the clamp breaks—preventing damage to the interior meter mechanism.

Intermediate Train—Model "G" Meter

THE intermediate train is assembled in the top casing of the meter, consists of three gears and three pinions of equal thickness and diameter, each having the same number of teeth. These parts are all made of Monel metal, proof against corrosive action in water carrying various forms of acids, alkali, etc. Train construction is such that it is absolutely rigid and its members always remain accurately centered. The removal of three Monel metal screws from the bottom train plate permits of immediate disassembly.





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Blake & Knowles Works
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Worthington Works
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Ladlaw Works, *Cincinnati, Ohio.*

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Power & Mining Works
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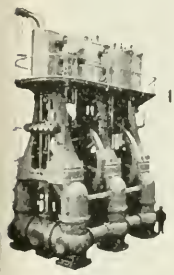
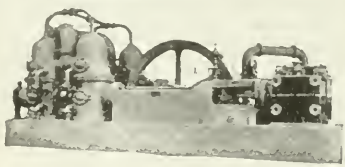


Vertical Triple Pumping Engine
19/36/54 x 17¼ x 36
150 lbs. steam
130 lbs. water
6 million gallons
170 million duty
City of Brockton, Mass.—1909



Horizontal Cross Compound Pumping Engine
27/60 x 10 x 42
For 300 to 7,000 lbs. water pressure
30 pumps sold to 12 companies priar to 1913

Horizontal Cross Compound Pumping Engine
24/54/ x 17 x 36
150 lbs. steam
8 million gallons
130 lbs. water
Over 165,000,000 duty
York, Pa., Water-works—1915

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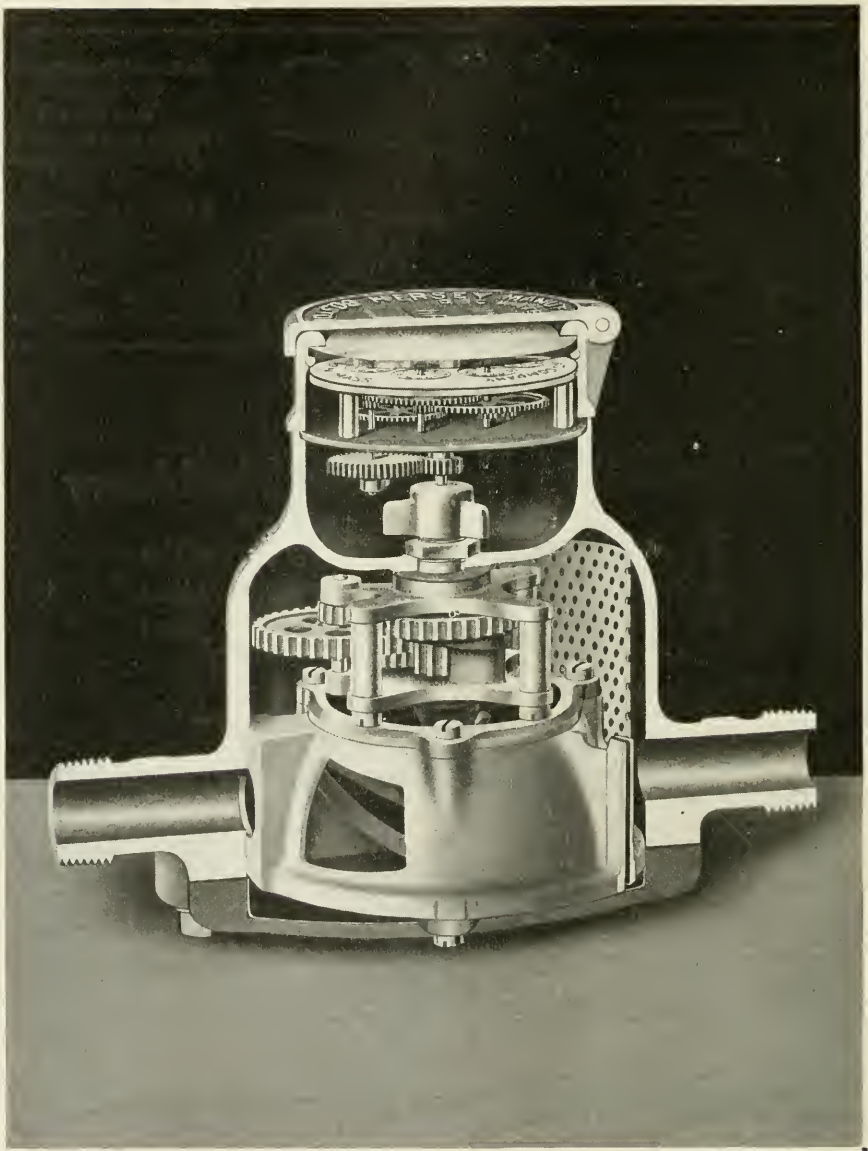

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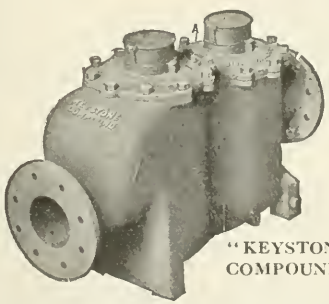

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COMPOUND"

"UTILITY"

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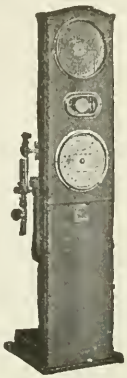

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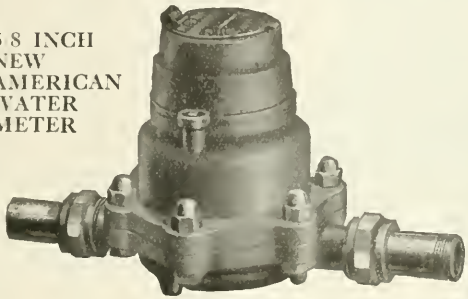
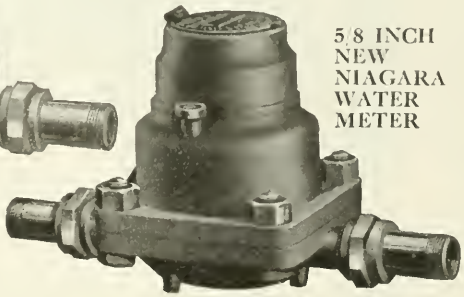


5/8 INCH NEW NIAGARA WATER METER



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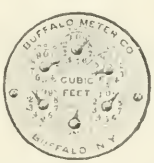

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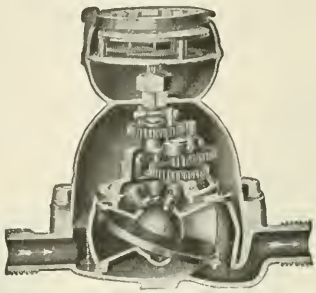

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WATER METERS

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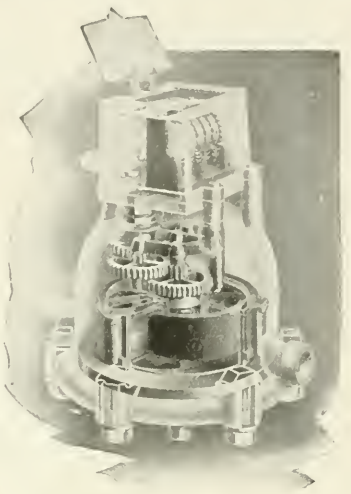
Union Water Meter Co.

WORCESTER, MASS.

"THEY SAY"

is not always a remark to inspire confidence, but if "they" make plain statements of plain facts, and all accounts agree, then what "they say" becomes valuable testimony.



Empire Water Meters

are the most sensitive, accurate, durable and long-lived water measuring devices made. This is not offered as our mere unsupported opinion, but is confirmed for your satisfaction by what "they say," quoted below:

From President of Water Co. in Maine:

"Since installation we have cut the consumption 40%, and unhesitatingly recommend EMPIRE meters to any Water Corporation."

From a New Hampshire Superintendent:

"We have about 850 EMPIRES. They give us very little trouble and are very satisfactory."

From Registrar of a Massachusetts Town:

"We have some EMPIRES that have been working steadily for over 20 years, and have given entire satisfaction."

From Town using nearly 2500 EMPIRES:

"Many of these meters have been in use for more than 20 years without one cent of expense to ourselves or the users."

Further details, illustrations and prices on request

NATIONAL METER COMPANY

Established 1870 **299 Broadway, New York**

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ATTENTION
WATER WORKS
OF NEW ENGLAND

A few reasons why we solicit your inquiries on Water-Works Pumping Equipment:

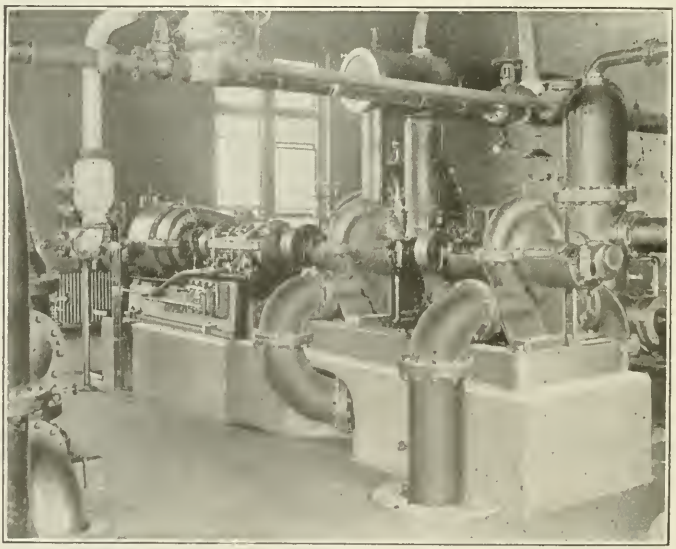
First. — We make a specialty of furnishing Complete Water-Works Pumping Units of all types.

Second. — Total responsibility of installation is assumed by us.

Third. — We relieve the purchaser of every detail and turn the complete unit over to him under actual operation and with guarantee.

Fourth. — Every unit installed to date has beaten its guarantee and has been completely accepted.

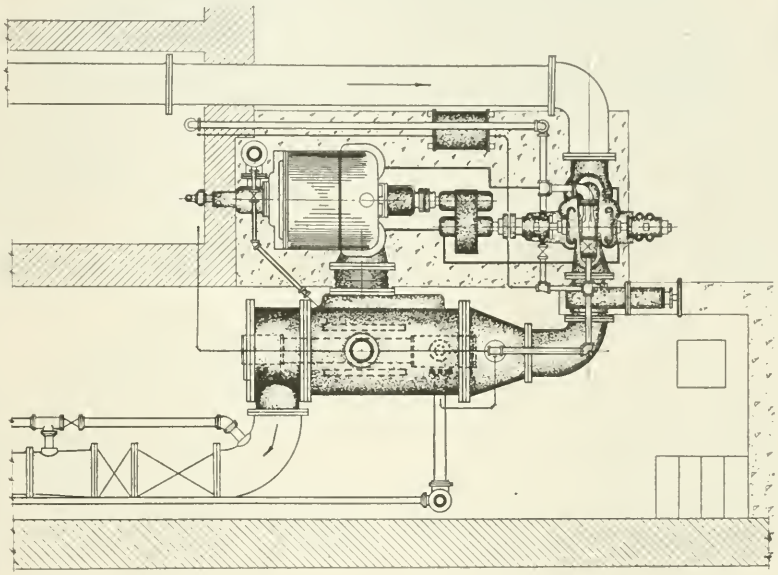
F. A. Mazzur & Co.
141 MILK STREET, BOSTON



Turbine-driven Pump at the Arlington Station of the Metropolitan Water Works, Boston, Mass.

Complete Water-Works Pumping Plants

BOILERS STOKERS STACKS SUPERHEATERS
ECONOMIZERS FEED HEATERS CENTRIFUGAL PUMPS
WATER WORKS CONDENSERS AIR PUMPS
FEED PUMPS FILTERS FOOT VALVES



Above illustration shows the general arrangement of a 5 000 000 G.P.D. centrifugal pump for 237 feet dynamic head and driven through reduction gears by a multi-stage Steam Turbine, exhausting into a discharge type water-works Surface Condenser with horizontal air and condensate pump underneath same. Installed by us in the City Water Works, Woburn, Mass., to plans and specifications prepared by H. M. Haven & W. W. Crosby, Engineers, Boston, Mass.

Duties of from 100 000 000 to 150 000 000 foot-pounds per 1000 pounds of steam used are obtained with such installations; the exact duty depending upon size, head, steam pressure, superheat and vacuum.

Installed costs are from **one fourth** to **one third** that of a reciprocating pumping engine, and overall economy, little, if any, less.

Where current is available and electric pumping desirable, we can furnish motor-driven Centrifugal Pumps, single or multi-stage, depending upon head.

WE INSTALL COMPLETE WATER-WORKS PUMPING EQUIPMENT FROM COAL PILE TO DISCHARGE MAIN.

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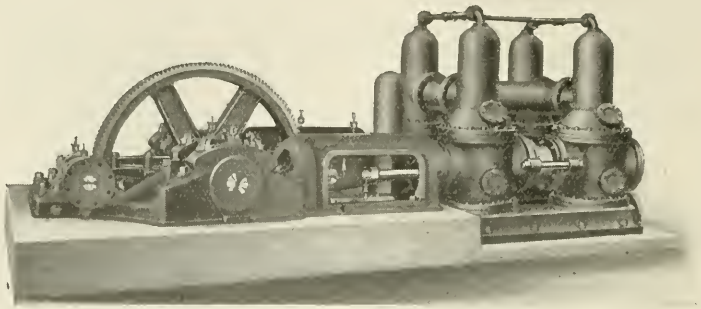

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WIRE TO WATER

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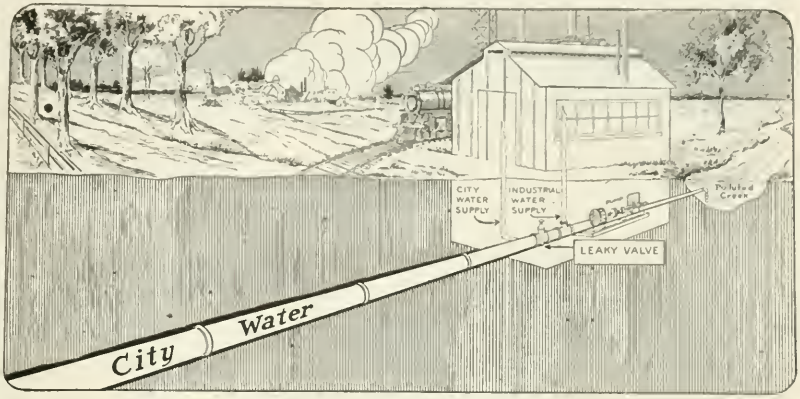

A leaky valve permitted polluted creek water from the industrial supply to enter the city water mains — fifteen funerals followed.

Bloomington, Ill., had a Safe Water Supply

At least part of it was safe — and then just over night a terrific typhoid fever epidemic broke loose. One hundred and thirty people fell sick from typhoid fever, over four hundred people were stricken with intestinal trouble, fifteen people died.* The thriving, prosperous city of Bloomington was plunged into the depths of suffering, sorrow and death.

What happened here has happened many times before, and in many places with but slight variation in setting.

A railroad company operating shops at Bloomington at a time of water scarcity pumped water from a polluted sewage-laden creek for manufacturing purposes. But this industrial water supply was connected by a valve with the city water supply. And the valve leaked —

So — typhoid bacteria entered the city supply, and the epidemic, so costly and so appalling, resulted.

And it all could have been prevented — all the suffering and the loss — the heartache avoided, had the industrial supply been sterilized by "W. & T." Apparatus and **Liquid Chlorine.**

One ounce of chlorine would have made twelve thousand gallons of that creek water disease-proof, would have made it incapable of spreading pestilence and death.

Two water supplies, one safe and the other unsafe, will always menace the health of a town. All industrial water supplies should always be chlorinated — cross connections between drinking water supplies and industrial water supplies should never be permitted unless the latter is sterilized.

W. & T. apparatus is installed all over the United States and is sterilizing water supplies at an average cost of one cent per twenty thousand gallons. Wherever installed, it is making the water safe to drink.

Can you afford to be without such economical and yet such invaluable protection?

Write to-day for our booklet, "Why Sterilize Water."

*Reference — Eng. News Record, May 13, 1920.

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Illustrated booklet upon request

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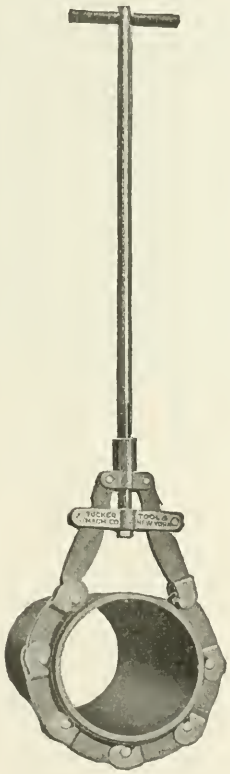

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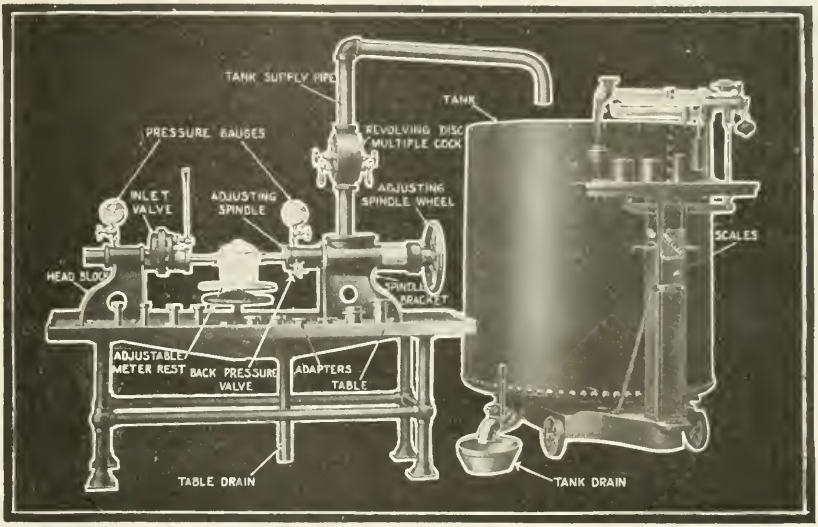

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We can interest you if you use a condenser.

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THE ROSS VALVE MFG. CO.

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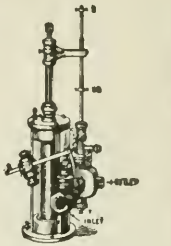
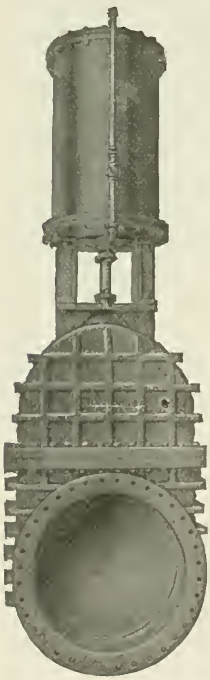


Standard for pumping church or parlor organs. Ask your organ builder for it or write us.



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Kennedy Valves in low, medium, and high pressure types and sizes meet all ordinary requirements and have always proven reliable and free from appreciable maintenance expense.

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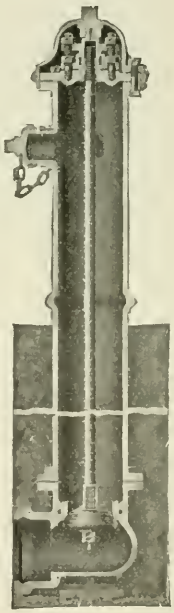

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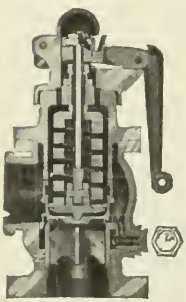

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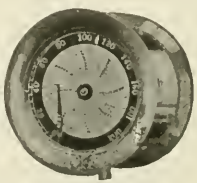

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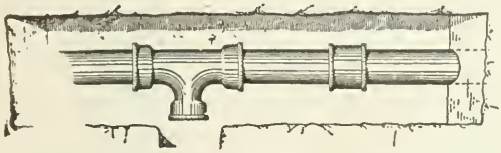
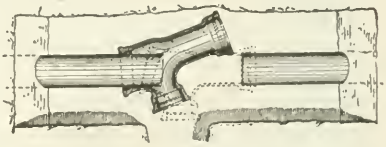
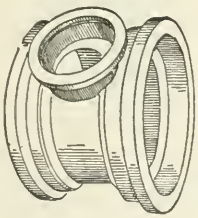


Old Way



Our Way



Connections economically and easily made with one fitting. Saves sleeve, cuts, lead and unnecessary work and material.

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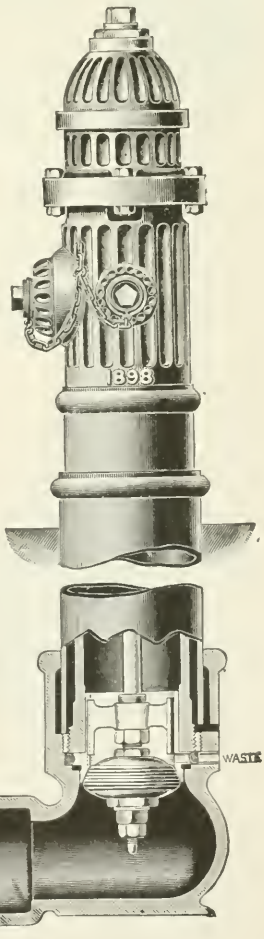

A half century of use has established their reputation as being the most economical, durable and simple hydrant.

Number in use exceeds total of all other makes combined.

Gate Valves

R. D. WOOD & CO. STANDARD
DOUBLE DISK
ANTI-FRICTION
EXTRA WEIGHT, FINISH
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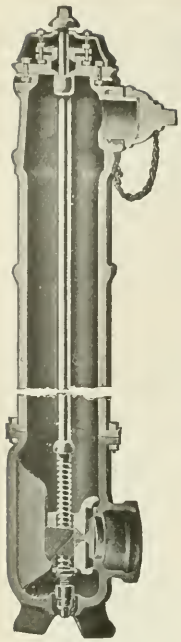

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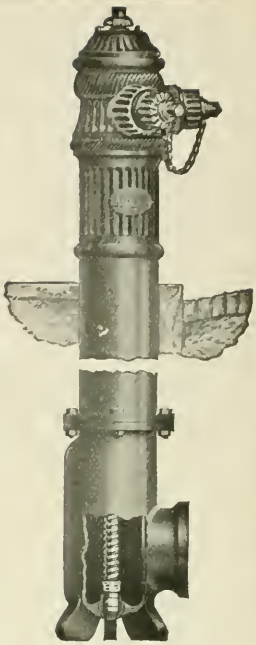
This hydrant is anti-freezing, because when the drainage is good no water is left in it to freeze.

The drip is directly in the bottom of the hydrant and drains perfectly. It is protected by its valve, which never leaves its socket and cannot be clogged.



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FIRE **HYDRANTS.**

YARD, WASH, AND FLUSH **HYDRANTS.**

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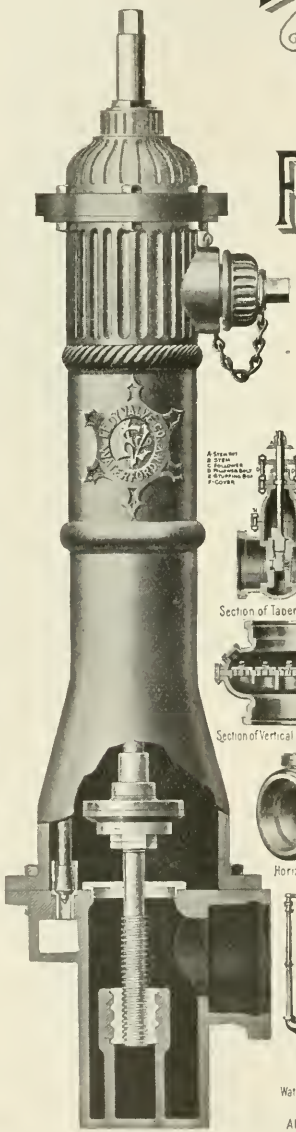
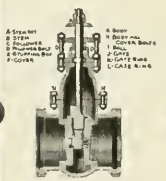
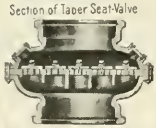


VALVE OPEN—DRIP CLOSED.

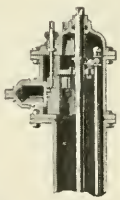


Section of Taper Seat-Valve



Section of Vertical Check-Valve

Horizontal Check-Valve

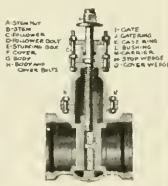


Hydrant with Independent Nozzle Cut off.

Indicator Post.

Hydrant with Water Crane Attachment.

Water Crane with Automatic Drip Valve.

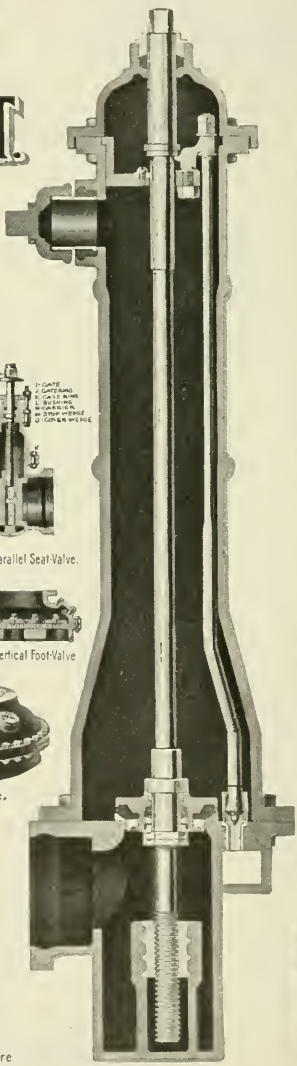


Section of Parallel Seat-Valve.

Section of Vertical Foot-Valve

Vertical Foot-Valve.

All Goods made by the EDDY VALVE COMPANY are manufactured exclusively at WATERFORD, N.Y., U.S.A.



VALVE CLOSED—DRIP OPEN.

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... OF ...

CAST IRON PIPE

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Special Castings for Water and Gas.
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JOHN D. ORMROD, President,
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Do you account for less than 85% of your pumpage?

Are you receiving full revenue from your manufacturing consumers?

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Thirty thousand feet — 2,500 bell and spigot joints — of U. S. Cast-Iron Pipe — laid over rough country — granite bowlders — sharp dips of from 12 to 20 feet under water — and all without a special casting or a bend of any kind.

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There were 2,500 joints, and out of all that multitude only three showed slight signs of leakage when the line was tested.

At one point the line dipped through a lake, dropped 20 feet under water, then rose to the shore on the other side. The lake was narrow, — we'll show you a picture of that later, — so you can imagine the tremendous strain to which those joints were subjected. With that in mind just recall that only three joints out of 2,500 showed even a slight leak. Some 2,497 joints perfect, in spite of the rocky-road-to-Dublin conditions almost everywhere.

Where was it? Medicine Canyon, Okla. What pipe was it? The pipe with 250 years' service record back of it, —

24″ Line looking South from Dam through Medicine Canyon.

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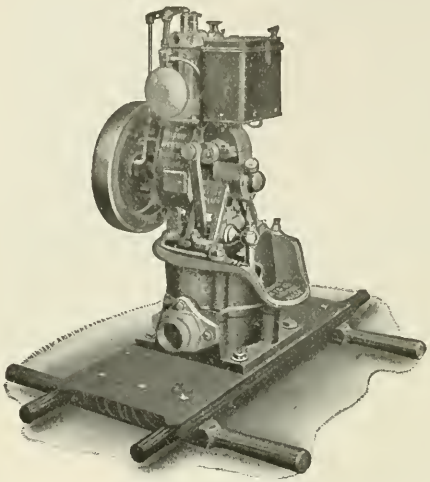

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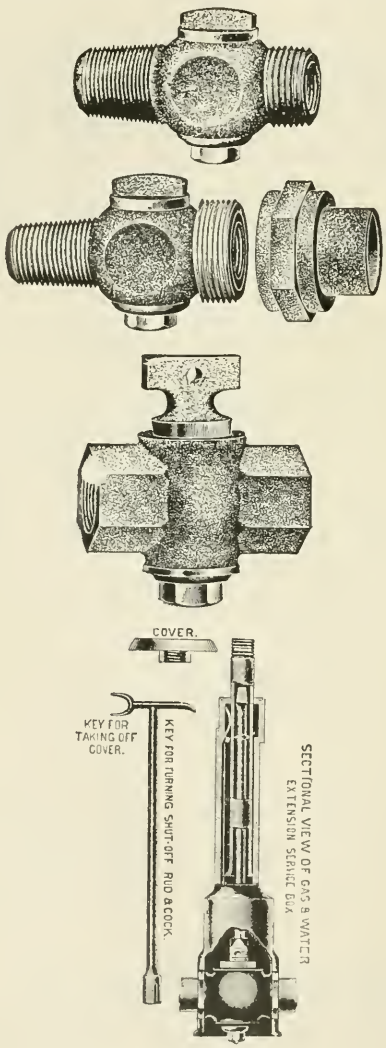

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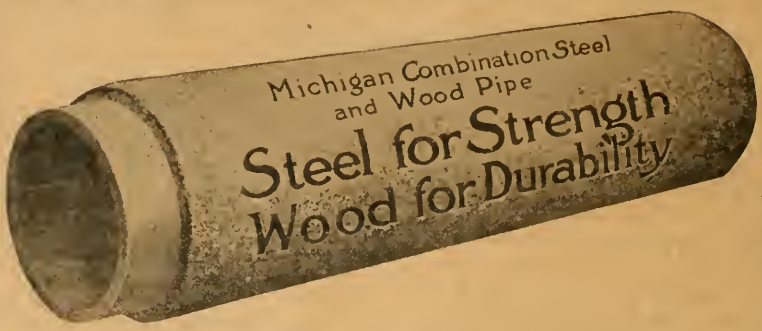

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